DENTAL AND ORAL RADIOGRAPHY

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A TEXTBOOK FOR STUDENTS AND PRACTITIONERS OF DENTISTRY

BY

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WITH 123 ILLUSTRATIONS

SECOND EDITION

ST. LOUIS
C. V. MOSBY COMPANY
1919

Press of
C. V. Mosby Company
St. Louis, Mo.

PREFACE TO SECOND EDITION

During the preparation of the second edition of this book the author has endeavored at all times to keep in mind the needs of the beginner in radiography rather than consider matters of interest to those who have progressed beyond this stage.

That radiography is essential in the practice of dentistry is no longer a debatable question. The wide interest being manifested in it by our profession and the numerous instances where dentists are installing their own x-ray laboratories bear eloquent testimony of this fact. While the author is willing to plead "guilty to a great degree of enthusiasm" regarding the value of the x-ray in dentistry, he feels that he is within reasonable bounds in asserting that the x-ray has done more to improve dentistry than any other agent that has come into it during the past ten years. If it were of value "in root canal operations only" the benefits to this field alone would justify the foregoing statement, for we must all acknowledge that as commonly practiced in the past this branch represented the greatest shortcoming of our profession.

Fortunately root canal work does not represent the only field in dentistry where the radiogram is a benefit, for it has been demonstrated that it is of equal value and in fact is often absolutely essential in the other branches of practice. These facts are not only now fairly well appreciated by dentists, but the laity have been quick to grasp them with the result that dentists who attempt certain operations without radiographic guidance are open to censure from their patients.

The awakening of the rank and file of the profession to the necessity of a more universal adoption of the x-ray has been slow, and it is doubtful if some will ever become fully conscious, as they continue to exhibit a lethargy toward this field which is either indicative of lack of foresight or sheer laziness.

In contrast to such, it is refreshing to recall that some members of our profession were quick to see the possibilities to den-

tistry offered through the adoption of the x-ray. Conspicuous among these was Dr. C. Edmond Kells, of New Orleans, who in 1896 (within the year following the discovery of the x-ray) installed x-ray equipment in his office and applied it to his dental practice. So great were his convictions and so genuine was his enthusiasm that in July, 1906, he took his x-ray equipment to Ashville, N. C., and there gave a clinic before the Southern Dental Association. Dr. Kells was the first dentist to make radiograms by placing small films in the mouth, and he also originated the plan of placing diagnostic wires in the roots of teeth.

Among those who shared Dr. Kells' foresight during those pioneer days and adopted the x-ray as part of dental practice are numbered such men as Drs. Van Wort, M. L. Rhein, E. W. Caldwell, T. P. Hinman, and Weston A. Price.

Within the last few years a large number of our dental schools have included radiography in their teaching curriculums and some have even shown the foresight of establishing it as a distinct department with equal rank and consideration with the other important branches. This will in time bear fruit which will result in a more adequate appreciation of the merits and possibilities of the x-ray and its inseparable relationship to dentistry.

The author wishes to gratefully acknowledge the assistance given him in the preparation of this edition by Dr. Julio Endelman, whose friendly criticism and interest have been a constant source of help. Grateful acknowledgment is also made to Dr. Richmond C. Lane, who was kind enough to contribute several radiograms from practical cases illustrating root canal operations, root resections, and cysts. The author has also been aided by various manufacturers of x-ray equipment who have furnished many cuts of value to the text, and last, but not least, the publishers have by their cooperation and patience through many delays rendered less irksome the task of the writer.

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PREFACE TO FIRST EDITION

This book has been written primarily as a textbook for students of dentistry. It is essentially a book for beginners, and as the majority of the dental profession are at present to be regarded as beginners in this comparatively new branch of dentistry, the author entertains the hope that it will prove of interest to practicing dentists who appreciate the value of the x-ray, and are desirous of adding radiography to their accomplishments.

A few years ago the x-ray was considered in the light of a cultural asset to dentistry, but today the far-seeing members of our profession have awakened to the fact that it is a real necessity.

The x-ray will give the maximum amount of service in dental practice only to such of our profession who master the technic of radiography, and in addition are possessed of an accurate knowledge of the anatomy and pathology of the dental and oral structures.

The author is indebted to the pioneers in dental radiography who have so generously contributed to its literature. Of these, much of value has been derived from the writings of such men as Drs. A. H. Ketcham, Weston Price, Sidney Lange, Howard R. Raper, F. L. R. Satterlee and Edward H. Skinner.

During the preparation of this work, the author has been aided by various manufacturers of x-ray equipment who have generously furnished cuts whenever requested. Grateful acknowledgment is also made to Dr. J. R. McCoy and to Laura Spruill who have made the drawings used as illustrations, and last and by no means least, to the publishers who have, through their forbearance and many courtesies, lessened the burdens of the writer.

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CHAPTER I

INTRODUCTION

When William Conrad Roentgen announced his discovery to the world, he called it the "x-ray," but the civilized world has for the most part seen fit to designate it the "roentgen ray" in honor of the discoverer. Roentgenology is, therefore, defined as "the study and practice of the roentgen ray as it applies to medicine and surgery."

For purposes of study, roentgenology may be divided into two distinct fields, depending upon the purpose for which the roentgen ray is to be utilized. In the first, which is the one enlisting the interest of dentists, it is used for the production of shadow pictures or radiograms. In other words, it embraces what is commonly called the "field of radiography," or "roentgenography."

The other branch mentioned includes the use of the roentgen ray for therapeutic purposes, and is known as "radiotherapy," or "roentgenotherapy." With this field, the dentist is happily not directly concerned, and, therefore, his responsibilities are not so great as the medical roentgenologist.

Of the various collateral sciences of medicine, there is no other which has developed more rapidly, or which has assumed a more important bearing in many branches of practice than has the science of roentgenology. With the increased appreciation of its value, and its wide adop-

tion, it has been developed through a comparatively short period of evolution, until now it can be regarded, broadly speaking, in the light of an exact science.

In spite of this fact, there is still apparent a great degree of misconception as to the responsibilities of one who is to actively engage in this work.

To the uninitiated, this field of labor often presents alluring possibilities, and they are all too apt to rush in without adequate preparation. To such, the reward of bitter disappointment must eventually come, when they become mired in the mud of their own poor judgment and lack of technical knowledge.

To avoid such an end, or perhaps what is almost as ignominious,—the acquiring of "a partial knowledge" of the subject, which at best can only carry one halfway upon the journey of success—the student should first come to a realization that the practice of roentgenology or any of its branches, requires more than a mere training in the mechanics of the x-ray laboratory.

Undoubtedly, many a man has, in the contemplation of x-ray apparatus for his office, given *serious thought to the type of equipment which he wished to install,* and has assumed that with a modern laboratory, he would be in a position to render the best of service. Such a misguided individual all too soon learns that *a very large part of the battle lies within himself,* and if his own knowledge is deficient, the finest equipment in the world will not make him a roentgenologist.

It is important, therefore, that those who contemplate any indulgence in the field of radiography should not underestimate the task that confronts them.

In addition to becoming familiar with the electrophysics of x-ray laboratory equipment, its practical application in his chosen field, the dangers which surround it if improperly used, one should realize that the real

practice of roentgenology begins when the x-ray picture, or radiogram, has been produced. It is quite impossible for such an image to be of value unless the roentgenologist is thoroughly familiar with the anatomy, physiology, and pathology of the field under examination; and even these qualifications are not adequate unless backed up by practical clinical experience.

For those who can qualify, there is a real field and a rare opportunity, and it will be found that every man who engages in this work will receive just that amount of recognition and respect from his colleagues to which his abilities entitle him.

One of the first things which the beginner should do is to become familiar with the terminology of this subject, and cultivate the habit of using terms correctly. Instead of using the term "x-ray picture," such an image should always be spoken of as a "radiogram," or as a "roentgenogram."

The physician or the dentist maintaining an x-ray laboratory should not be called "an x-ray specialist," but should be spoken of as "a medical or a dental roentgenologist."

Not infrequently, we hear physicians or dentists speaking of a dental radiogram as a "dental x-ray." Such an expression only exposes their crudity of thought, and certainly expresses nothing else.

It is thought by some terminologists that in addition to always speaking of the x-ray as the roentgen ray, in honor of the man who discovered it, we should include the name roentgen in every descriptive word connected with the work. To such, the term "radiograph" (verb) and "radiogram" (noun) will doubtless appear improper, but the author feels justified in continuing their use, as these words are thoroughly descriptive and less cumbersome than "roentgenograph" and "roentgenogram."

For the same reason, the term "radiography" is preferred rather than "roentgenography" to designate the art of making radiograms.

Briefly summarized, the following roentgen terminology will be found to be quite adequate:

Roentgen ray, or X-ray:	A phenomenon in physics discovered by William Conrad Roentgen.
Roentgenology, or Radiology:*	The study and practice of the roentgen ray as applied to medicine and surgery.
Roentgenologist, or Radiologist:*	One skilled in roentgenology, or radiology.
Roentgenogram, or Radiogram:	The shadow picture produced by the x-ray upon the photographic emulsion.
Roentgenograph, or Radiograph:	(Verb.) To make a roentgenogram, or radiogram.
Roentgenography, or Radiography:	The art of making roentgenograms, or radiograms.
Roentgenotherapy, or Radiotherapy:*	Treatment by the application of the roentgen ray.
Roentgen dermititis, or X-ray dermatitis:	Skin reaction due to too strong or too often repeated application of the roentgen ray.
Roentgenographic examination, or Radiographic examination:	The examination and study of the shadow pictures produced by the x-ray upon the photographic emulsion.
Roentgen diagnosis, or X-ray diagnosis:	Diagnosis by aid of the roentgen ray.
Pathoroentgenography, or Pathoradiography:†	The study of pathologic lesions as revealed by the radiogram, or roentgenogram; it implies and renders imperative a knowledge of the pathology and of the interpretation of normal and abnormal tissue densities as recorded in the radiogram.
Roentgenize:	To apply the roentgen ray.
Roentgenization:	The application of the roentgen ray.
Roentgenism:	The untoward effect of the roentgen ray.

*The term is rather confusing, as it could also refer to the practice and therapy of radium or other radiotherapeutic agents.

†Terms suggested by Dr. Julio Endelman.

Some writers add other descriptive terms to the foregoing list, but the author feels that a terminology should be just as brief as is consistent with adequate description; hence, several terms appearing in current literature on different phases of roentgenology have been omitted.

CHAPTER II

THE NATURE OF THE X-RAY AND ITS DISCOVERY

In order to gain an intelligent conception of the x-ray, it is quite necessary that the student start with a consideration of certain phases of electrophysics, and radiant energy, or in fact the very foundation of matter itself.

According to the most plausible theories and beliefs, all matter is suspended or contained in the medium known as ether, which is an elastic medium filling all space, interatomic and interelectronic, as well as all other space of which we have any knowledge.

Furthermore, many facts brought out by the close study of chemistry and physics seem to justify the belief that all substances of matter are composed of minute particles called "molecules," and that each molecule is made up of two or more elements called "atoms," while these atoms are also further divided in particles known as electrons.

These electrons, or units of matter, are never still, but are in a constant state of motion or vibration, each substance having its own specific atom and the electrons of such atoms having their own rate of vibration.

The vibration of these electrons produces disturbances in the ether know as "ether waves" which vary in length according to the rate at which electrons are vibrating. If the rate of vibration of the electrons be changed or disturbed, there is a change in the ether waves, resulting in a corresponding change in the phenomenon produced.

If this theory of matter is correct, as the evidence of

modern science would lead us to believe, all matter then is made up of the same constituents, and its various forms are determined, not by any essential difference of composition, but by the number, arrangement and amount of motion of the ultimate particles making up the atom.

All this has a practical significance to us in understanding the phenomenon which we call the x-ray. As stated before, it is known that a certain rate of vibration of electrons will produce other waves resulting in a definite phenomenon, while a change in this rate will produce an entirely different phenomenon. For instance, a slow rate of vibration (75,000,000 per second) produces what are known as electromagnetic waves. A little higher up the scale where the electrons are made to vibrate faster, heat waves appear. Another increase, and light waves appear. If we continue to accelerate the rate of vibrations of the electrons, there will be produced successively ultra-violet, or Finsen rays; then cathode, or radium, rays, and finally the x-ray.

It will then be seen that the x-rays are produced as the result of the most rapid rate of vibration of which we have any knowledge. In the laboratory this phenomenon is produced by the sudden stopping of a stream of rapidly moving free electrons in a vacuum tube which has been exhausted to one millionth of an atmosphere.

The x-ray, therefore, may be defined as that form of radiation which emanates from a highly exhausted tube when an electric current of high tension is passed through the tube. The object of the vacuum tube is to establish a medium in which all source of resistance is removed, so that the electric current may excite the exquisitely rapid vibrations necessary to produce the phenomenon desired, the electric current being the source of excitation.

The radiation thus produced gives neither heat nor

light, nor can it be deflected, reflected, or polarized. In fact, it can only be recognized by its effect upon the photographic plate and upon such chemicals as willemite, calcium, and tungstate, which fluoresce or glow under its influence.

The Discovery of the X-ray

The x-ray was discovered in 1895 by William Conrad Roentgen, Professor of Physics, at the Royal University

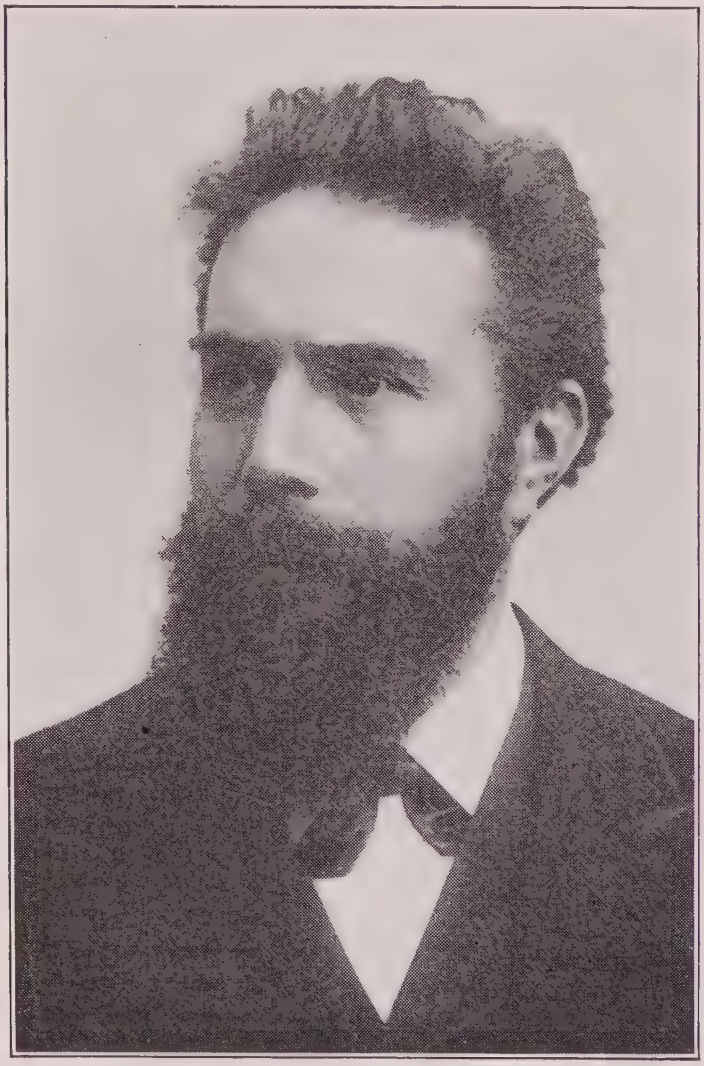


Fig. 1.—William Conrad Roentgen.

of Würzburg, in Germany. This discovery, marking as it did, a distinct epoch in the science of medicine, was received by the world with incredulity and amazement, for

its reported possibilities savored almost of the occult. "A new ray had been discovered by means of which it was possible to look through opaque substances."

While it fell to the lot of Professor Roentgen to make this discovery, there is no doubt but that other experimenters in the field of physics, unconsciously produced this same ray. In fact, its discovery was made possible by the work of other scientists who preceded Roentgen and laid the foundation for its advent.

Fig. 2.—Michael Faraday.

Of these, Michael Faraday was the pioneer. In 1831 he discovered electric magnetic induction, which made possible the induction coil and the other electric machines

utilized to generate currents of great potential. As early as 1838 he conducted a series of experiments to determine the effect of electric discharges upon rarified gases, and invented the terms "anode" and "cathode" for positive and negative electrodes.

In 1857 Geissler constructed the first vacuum tubes and it was noted at this time that an electric discharge passed through these tubes would produce a peculiar

Fig. 3.—Sir William Crookes.

glow or phosphorescence, the coloring of which depended upon the character of the rarefied gas contained in the tube. This phenomenon became known as "fluorescence."

A few years later (1860) Professor Hittorf, a celebrated physicist of Münster, conceived the idea of exhausting the Geissler tube to a higher degree of vacuum and found as a result an increased resistance to the pass-

ing of the electric discharge, and that the color of the rarefied gases under fluorescence, varied with the degree of rarefication. He also discovered another fact which was to have an important bearing upon the work of later experimenters, and that was that the luminous discharge in a Geissler tube *could be deflected by a magnet.*

The important work of these early experimenters was followed later (1878) by Sir William Crookes, who suc-

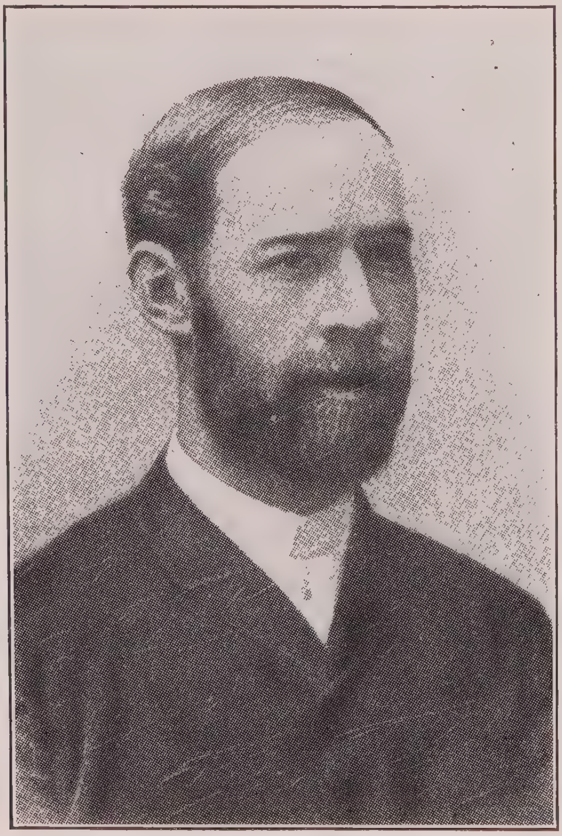


Fig. 4.—Heinrich Hertz.

ceeded in constructing a more perfect vacuum tube, that is, one that could be exhausted to a much higher degree of vacuum. With these improved tubes, Crookes discovered that with a sufficiently high vacuum the luminous glow within the tube disappeared, and demonstrated that within it there was a rectilinear radiation from the cathode, which he conceived as being a projection of particles of highly attenuated gas at exceedingly high veloc-

ity. To this radiation he gave the name "cathode rays," and because of the peculiar behavior of gas in this exceedingly rarefied state, he concluded that it was as different from gas in its properties as ordinary air or gas is different from a liquid. He found that the impact of the cathode rays against the wall of the tube would produce within it a greenish "phosphorescence" or "fluorescence" and an increase in temperature; also that these rays could be intercepted by metallic plates within the tube. By concentrating the rays at the focus of a concave cathode, he was able to produce a brilliant fluorescence and a very high temperature, both at the walls of the tube and in various substances within it. *Without doubt, Sir William Crookes unconsciously produced the x-ray in the course of these experiments.*

In 1892 Professor Heinrich Hertz discovered that cathode rays would penetrate gold leaf and other thin sheets of metal placed within the tube. Soon after this discovery, Hertz died, and his experiments were continued by his assistant, Lenard, who was able to demonstrate that many of the phenomena of the cathode rays could be observed outside of the Crookes tube. By closing a vacuum tube at the end opposite the cathode with a thin sheet of aluminum, he demonstrated that a radiation proceeded through or from the aluminum walls of the tube which would pass through many substances opaque to ordinary light, and after passing through such substances, it would excite fluorescence in crystals of barium platino-cyanide, and would affect sensitive photographic plates in much the same manner as ordinary light. Lenard considered that all these phenomena were due to the cathode rays alone, although in the light of our present knowledge, there is no doubt that, not only in his experiments, but in those of Crookes, Hertz, and other investigators, x-rays were produced. However,

they were not recognized as such until 1895, when Professor Roentgen startled the world by the announcement of his discovery.

Upon the memorable day of his discovery, Professor Roentgen was duplicating one of Lenard's experiments in the laboratory of the Würzburg University. The experiment consisted of passing an electric current through a Crookes tube covered with black cardboard, to test its fluorescence upon a piece of cardboard coated with barium platino-cyanide. A fresh specimen of this chemical had been prepared and spread upon the cardboard which was placed against the wall on the opposite side of the room to dry. The room was darkened and the current was passing through the tube, when to his amazement, Roentgen noticed that the chemically covered cardboard on the other side of the room was glowing with a wierd fluorescence. He approached the cardboard, and in doing so, passed between it and the Crookes tube, and beheld his shadow upon the cardboard. Picking up a book, he held it in front of the screen and noticed that it also cast a shadow. He then discovered that the luminous glow or fluorescence on the cardboard appeared and disappeared with the turning on and off of the current. With the tube operating, he picked up the cardboard, and while examining it, noticed the shadow of his hand on its surface, the bones appearing much darker than the soft parts of the hand. He also found that the fluorescence was produced in the cardboard regardless of whether the chemically coated side was turned toward or away from the Crookes tube, showing that the rays had the power to penetrate substances at a distance from the tube.

Further investigation proved that the radiation producing these phenomena emanated from *the point of impact of the cathode rays* against the glass wall of the Crookes tube; that nearly all substances were trans-

parent to it, although in widely different degrees, varying roughly with their density; that the radiation was rectilinear; that it could not be refracted, reflected, or deflected by a magnet. Hence it was plain to Roentgen that these rays were quite different from the cathode rays of Crookes, Hertz, or Lenard.

Using photographic plates wrapped in black paper to protect them from ordinary light, he obtained with these new rays shadow pictures of metallic objects in a wooden box, and of the bones of the hand.

He continued his experiments both with the fluorescent screen and the photographic plate, and in December, 1895, communicated his discovery to the Physico-Medical Society of Würzburg. Being unable to determine the exact nature of this new ray other than classing the phenomenon as longitudinal vibrations of ether, Roentgen called it the x-ray, the letter "x" representing the unknown in the mathematical formula. Even today the exact nature of the rays has not been determined, although the concensus of opinion seems to be that they are violent ether pulses set up by the sudden stoppage of the cathode rays as they strike upon the walls of the tube or upon any intervening obstruction. If this theory be correct, x-rays are of the same general nature as light waves, but of such short wave length that they lie outside the visible spectrum.

CHAPTER III

HIGH TENSION ELECTRIC CURRENTS—MAGNETISM—ELECTROMAGNETIC INDUCTION

High Tension Electric Currents

As stated previously, the x-ray is produced when an electric current of high tension is passed through a vacuum tube. Therefore, let us consider the character of this current and the means employed to produce it.

There are several kinds of electric currents, but of these we need concern ourselves only with two—the direct current, commonly designated by the abbreviation D.C.; and the alternating current, designated as A.C.

The *direct current* is one in which the electricity flows along a conductor *in one direction* at a uniform rate of pressure, while the *alternating current* flows along a conductor first in one direction, then reverses and flows in the opposite direction, these changes taking place with great rapidity (50 to 120 per second). Such a current in making these changes is said to have completed a cycle, and its frequency is designated by the number of alternations which occur each second.

A high tension current is one which has high voltage, or, as it is expressed in electrical terms, has great electromotive force, or pressure.

The *Volt* is defined as the unit of electromotive force, and is analogous to the pressure caused by a difference in level of two bodies of water connected by a pipe—the pressure tends to force the water through the pipe and

the electromotive force or voltage tends to cause the electric current to flow along a conductor.

The *Ampere* is the unit of current strength, or in other words, the amount of current passing a given point on a conductor in a given time. If we again use the analogy of the two bodies of water at different levels connected by a pipe, it would be the amount of water which could pass through the pipe in a given time.

The *Ohm* is the unit of resistance. Just as the water in flowing through a pipe is resisted somewhat in its passage by the friction offered by the surface of the pipe, or by the limited capacity of the pipe, so, likewise, the electric current is resisted in varying degrees in its passage along a conductor, the degree of resistance depending upon the degree of conductivity of the material used as the conductor, its length, cross section, etc.

The *Watt* is the unit of electromotive power or the ability of a current to do work. The wattage of a current is determined by the voltage, or pressure, and the amperage or quantity, the wattage of a given current being determined by multiplying the voltage by the amperage.

From the foregoing, then, we see that the character of an electric current is determined by several factors, all of which must be taken into consideration.

If we wish to know the strength of a given current, we have but to remember this strength will depend upon the pressure or electromotive force and the resistance offered by the conductor through which the current is passing, just as the strength of a stream of water flowing from a tank would depend upon the pressure and the size of the pipe carrying the water. In other words, the strength of the electric current equals the pressure divided by the resistance. Reducing this to an equation we have—

$$\text{Amperes} = \frac{\text{volts}}{\text{ohms}} \text{ or C equals } \frac{\text{E.M.F.}}{\text{R}}$$

This is known as "Ohm's Law" and is one of the fundamental laws upon which electrical science is based. This important law has two other forms which make it possible to learn the relationship and amount of any of these three units, provided two are known. For instance, by transposing the formula of Ohm's law, we have—

$$\text{Volts} = \text{amperes x ohms, or E.M.F.} = \text{C x R.}$$

If we wish to determine the resistance offered by a given conductor, we apply the formula as follows:

$$\text{Resistance} = \frac{\text{E.M.F.}}{\text{amperage}} \text{ or R} = \frac{\text{E.M.F.}}{\text{C}}$$

As stated before, the current which is passed through the vacuum tube to generate the x-rays must be a current of high tension, or great pressure; or, expressed in the terms of the units just described, it must have very high voltage. The ordinary lighting current of 110 volts is inadequate, as this current is of far too low potential to pass through the tube, as the vacuum offers great resistance, a resistance which to the ordinary current amounts to an absolute nonconductor. We are obliged, therefore, to make use of some means which will produce a current of great voltage, a current, we will say, of at least 75,000 to 150,000 volts.

To do this, we must make use of one of the electric machines which can generate such a current by utilizing the principle of *electromagnetic induction.* Lest the student become confused, we will first review very briefly some of the elementary principles of electromagnetism and its relation to the production of the high tension current necessary in x-ray production.

Magnetism

Magnetism is the term applied to substances which have the property of attracting small pieces of iron. A material possessing this property was first found by the ancients at Magnesia, in Asia Minor, from which fact arose the name magnet.

The *natural magnet* is an oxide of iron and is also called the lodestone. *Artificial magnets* can be made by rubbing a bar of hard steel with a lodestone, or with another artificial magnet, or by means of an electric current. Artificial magnets acquire the same magnetic properties which the lodestone or natural magnet possesses except that they acquire them to a much greater extent, and are, therefore, always used in preference to natural magnets.

In addition to the property of attracting small pieces of iron, magnets have other characteristics worthy of mention, such as *polarity*, or the property of assuming, when suspended and perfectly free to move, a north and south position. The compass is quoted as a familiar example.

At the ends of a magnet, or in other words at its *poles*, the greatest power or attraction exists. This is easily illustrated by placing one end of an ordinary magnet in some iron filings and withdrawing it. The filings will cling to it in great numbers, as they will likewise do to the other end of the same magnet if it too be placed in the filings. The middle of the magnet (or that portion midway between the two poles), however, does not possess this property; but as the ends are approached, the attraction increases until the poles are reached, where it reaches the maximum.

In observing the action of the two poles of a magnet in attracting the iron filings, no particular difference is

observed. *They both attract the iron filings.* There is a difference, however, which may be shown by experimenting with two magnets, one of which should be suspended at its center like an ordinary compass, while the other is held in the hand. If the north pole of the magnet held in the hand is moved near the north pole of the suspended magnet, *they will repel each other.* Likewise if their south poles are approached, *they will repel each other.* But if the north pole of one be placed near the south pole of the other, they will *attract each other.*

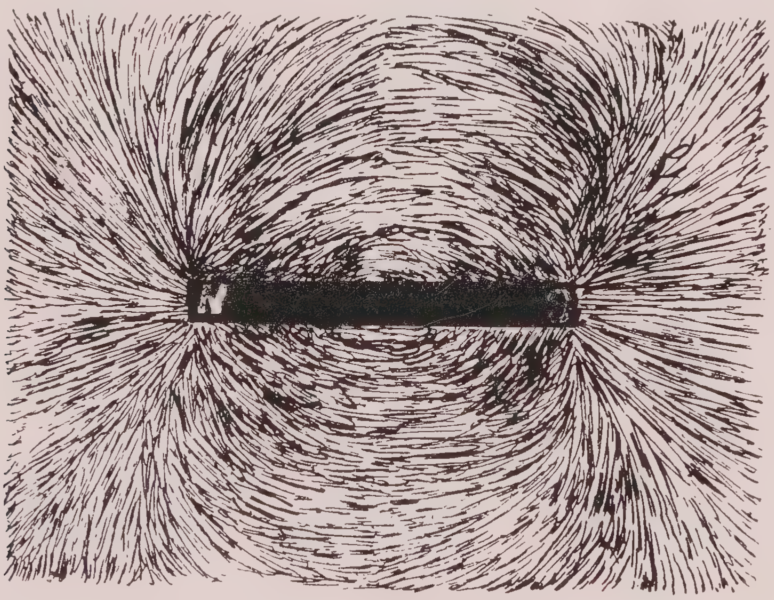


Fig. 5.—The action of iron filings in forming definite curved lines about an ordinary bar magnet indicates that the magnetic field exerts its influence in certain definite directions which are called "the magnetic lines of force."

This shows that *like poles repel each other, while unlike poles attract each other.*

The space surrounding a magnet which is subject to its influence is known as its *magnetic field.* The presence of this magnetic field is easily demonstrated by placing a magnet under a sheet of paper upon which iron filings have been evenly spread. By tapping the paper lightly, the filings will form into a series of curved lines extending from one pole of the magnet to the other pole, as illustrated in Fig. 5. The formation of these definite

curves indicates that the magnetic field exerts its influence in certain definite directions which are called *the lines of magnetic force.* These lines of force start at one pole of the magnet, pass in curved lines around to the opposite pole, where they re-enter and pass on through the magnet again, so that if any line is followed through its entire length, one will eventually come back to the starting point, as shown in Fig. 6.

It is by virtue of its *magnetic field,* that a magnet has the power of attracting pieces of iron. When a piece of

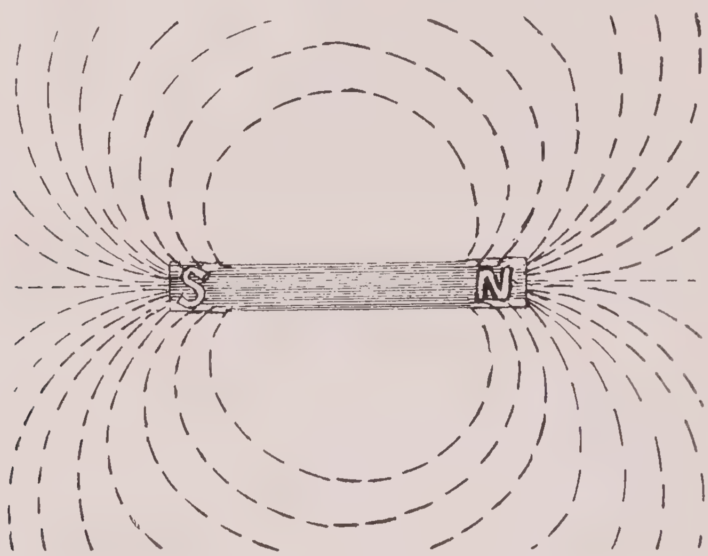


Fig. 6.—Diagrammatic illustration of the magnetic lines of force.

iron is brought under its influence, *it becomes a temporary magnet,* and for the time being has its two poles. If the north pole of a magnet is brought close to a piece of iron, a south pole will be induced in the iron next to this north pole, and a north pole in the portion farthest from it. The attraction is then exactly similar to the attraction between two permanent magnets when two unlike *poles* are brought together. This action of a magnet in developing magnetism in iron placed in its magnetic field is called *magnetic induction.*

When a piece of iron is in contact with a magnet, the attraction is greatest; but actual contact is unnecessary

to magnetize the iron, as it need only be placed within the magnetic field, or, in other words, within the magnetic lines of force of the magnet.

Magnetism may be induced in iron in another way not yet described, and to us this is of great importance. If an ordinary electric current is passed through a coil of wire, *the coil becomes equivalent to a magnet and is surrounded by a magnetic field* similar to that of a bar magnet. Such a coil of wire is called a *helix,* and if its length is many times its diameter, it is called a *solenoid.*

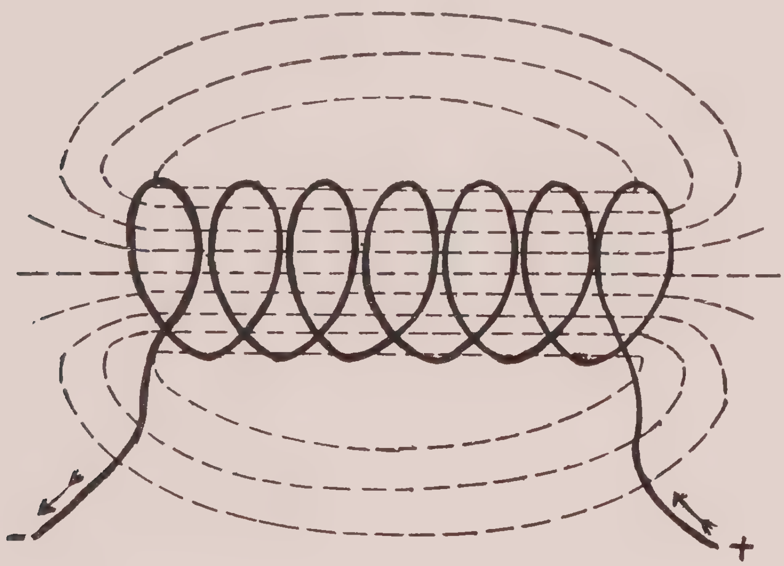


Fig. 7.—Diagrammatic illustration of the magnetic field surrounding a coil of wire through which an electric current is passing.

Since a *solenoid* is surrounded by a magnetic field similar to that of a magnet (see Fig. 7) it follows that a solenoid is capable of magnetizing pieces of soft iron and attracting them in the same way as does an ordinary steel magnet. The magnetic field of a solenoid is strongest within its windings and therefore if a bar of soft iron is placed within the coil, the bar will be much more strongly magnetized than if placed in any other position about the coil. Such a coil adapted to carry a current and provided with a soft iron bar or core is called an *electromagnet* (Fig. 8).

In order to permit the wire to be closely wound and at the same time to allow the current to pass through each turn, the wire must be covered with insulation throughout its length. It should also be remembered that the *iron core within the solenoid* remains a magnet *only while the current is passing* through the coil, as "*only electric charges in motion produce magnetic effects.*"

Electromagnets are much more powerful than ordinary magnets; that is, their fields have much greater strength,

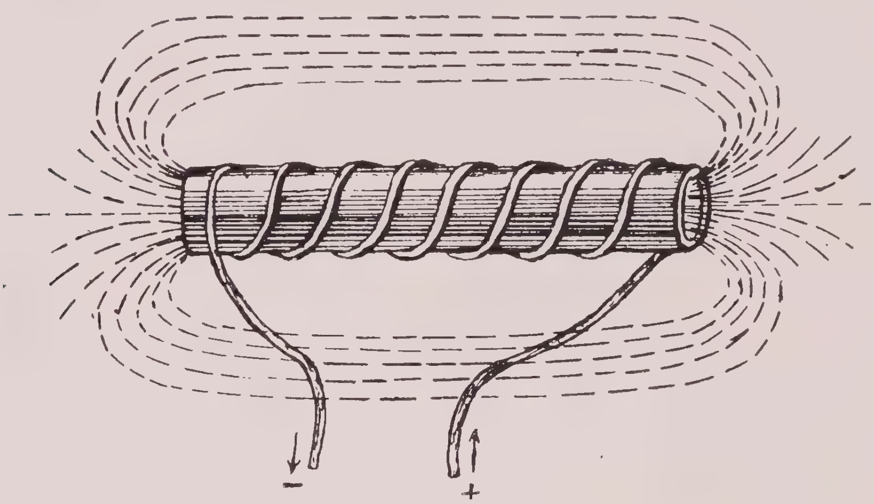


Fig. 8.—An iron bar placed within the windings of a solenoid is subject to its magnetic field and becomes a magnet.

for *the field of the electromagnet is equal to the sum of the field due to the core, plus the field due to the current passing through the coil.*

Thus far we have discussed the fact that a magnetic substance in the field of an ordinary magnet, or a conductor carrying an electric current, is magnetized. This phenomenon, we know, is due to *magnetic induction.* It is also a fact that an *electric current may be induced in a conductor by causing the latter to move through a magnetic field.* It makes no difference whether this field comes from an ordinary magnet or from an electric charge passing through a conductor. *This action of a*

magnet or of a current on a conductor moved in its field is called electromagnetic induction.

Principles of Electromagnetic Induction

If the ends of a coil of wire are connected with a galvanometer (Fig. 9) and the coil is moved down over an ordinary magnet, the galvanometer will show that a momentary electric current has passed through the coil. The current continues as long as the coil is in motion,

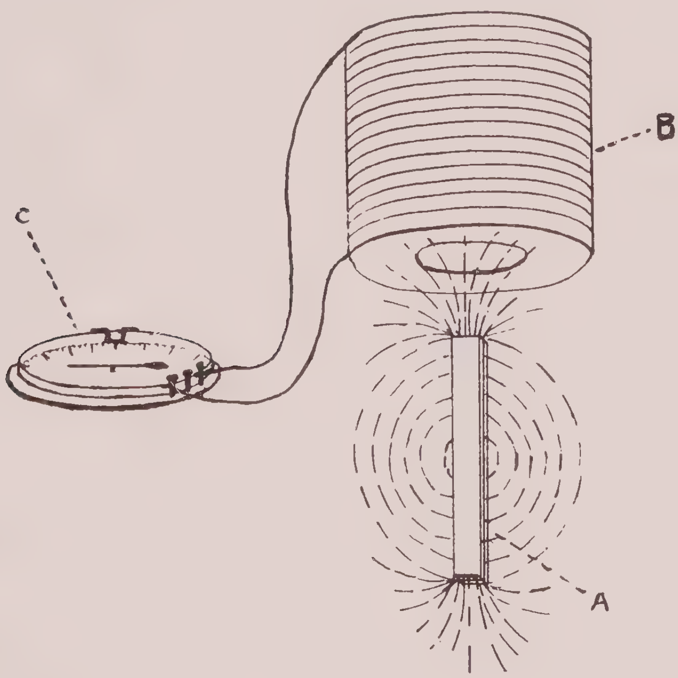


Fig. 9.—*A,* magnet with diagrammatic illustration of "magnetic lines of force" surrounding it. *B* shows a coil of wire connected to a galvanometer, *C.*

and ceases as soon as the coil is brought to rest. If the coil is withdrawn from the magnet, a current is also induced which flows in an opposite direction to the current which was induced when the coil was carried down over the magnet.

These induced currents are produced by the field surrounding the magnet moving or cutting across the wires composing the coil. If a current is passed through the coil, it creates a magnetic field, and, on the other hand,

the movement of a magnetic field within the coil produces a current.

As a solenoid is surrounded by a magnetic field similar to an ordinary bar magnet, it follows that if a solenoid carrying a current were thrust within (Fig. 10) another coil, induced currents will be produced in the latter. These induced currents, as in the case where the magnet is used, only flow while there is a relative movement between the magnetic field and the conductor. When the

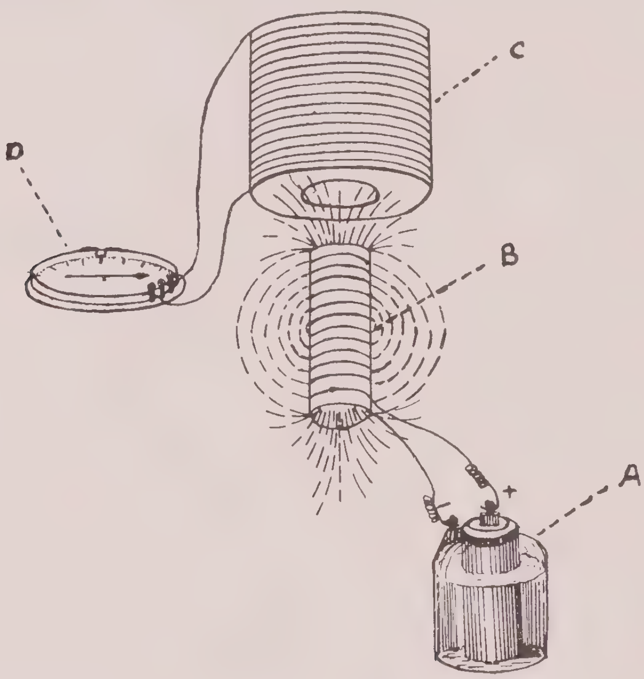


Fig. 10.—*A*, battery from which an electric current is passing through the solenoid, *B*; *C*, large coil into which the smaller coil *B* is passed; *D*, galvanometer.

solenoid is passed into the other coil, the induced current will flow *in an opposite direction to the current flowing in the solenoid,* and upon *withdrawing the solenoid, the induced current will flow in the same direction as the current in the solenoid.*

Suppose the two coils just described are placed one within the other (there being no current passing) and while in this position a current is started in the inner coil. Upon the passage of the current in the inner coil, a momentary current is induced in the outer coil, just the

same as if a magnet had been moved within it, as shown in Fig. 9. This induced current remains only while the current in the inner coil is increasing in value from zero to its normal strength. As soon as this normal strength is reached, the induced current ceases to flow. Now if the circuit of the inner coil is broken and its current ceases to flow, at this instant another momentary current is induced in the outer coil, which flows in a direction *opposite* to the current which was induced by starting the current. These two induced currents created by starting and stopping the primary current, or in other words, by "making" and "breaking" the current, are not of equal strength, the one produced by the *"break"* of the current being much the stronger.

Such an instrument arranged with one coil within the other, but without any connection between the two coils, is known as an "induction coil." The inner coil which is usually supplied with an iron core, is known as the "primary coil;" and the outer coil, in which the current is induced, is known as the "secondary coil."

Induced currents are greatly intensified when soft iron cores are placed within the primary coils, as the cores become magnets and increase the strength of the field by adding largely to the lines of force therein.

If an induction coil is constructed with the same number of turns of wire in the "secondary" as are present in the "primary," the current induced in the secondary will be exactly equal to the current passed through the primary. *The voltage will not be increased.* On the other hand, if the secondary contains twice as many turns as the primary, the induced current will be double the voltage of the primary, *as each turn of the secondary induces a current in the turns directly adjacent to it,* which must be added to the current induced in the first layer by the action of the primary current. Therefore,

it should be apparent that as we increase the number of turns in the secondary, we increase the E.M.F., or voltage. This increase of E.M.F., or voltage, is due to the phenomena of "self-induction" which is the principle utilized in all x-ray machines or other electrical apparatus used to "step up" the E.M.F., or voltage.

CHAPTER IV

X-RAY MACHINES

RHUMKORFF OR INDUCTION COIL—TESLA OR HIGH FREQUENCY COIL—INTERRUPTERLESS TRANSFORMER

The Rhumkorff or Induction Coil

The Rhumkorff, or "induction coil," which is the most common type of x-ray machine in use today, consists of two principal parts, each of which is a coil of wire, one being contained within the other, although they have no electrical connection (see Fig. 11).

The inner coil, or "primary," as it is called, consists of a few turns of very coarse insulated wire wrapped about a bundle of soft iron which is known as "the magnetic core."

The outer coil, or "secondary" is made up of a great many turns of fine insulated wire. It has been estimated that in a 12-inch induction coil the secondary coil is wound with between twenty and thirty miles of wire. This, of course, makes possible an enormous number of "turns of wire" so that when we consider that each turn of the secondary induces a current in the turn directly adjacent to it, which must be added to the current induced in the first layer by the action of the primary current, the sum total of the current coming from the secondary amounts to something tremendous.

To compute the E.M.F., of the induced current (or that coming from the secondary), we have but to remember that "the E.M.F., of the induced current is to that of the primary current, as the number of turns in the

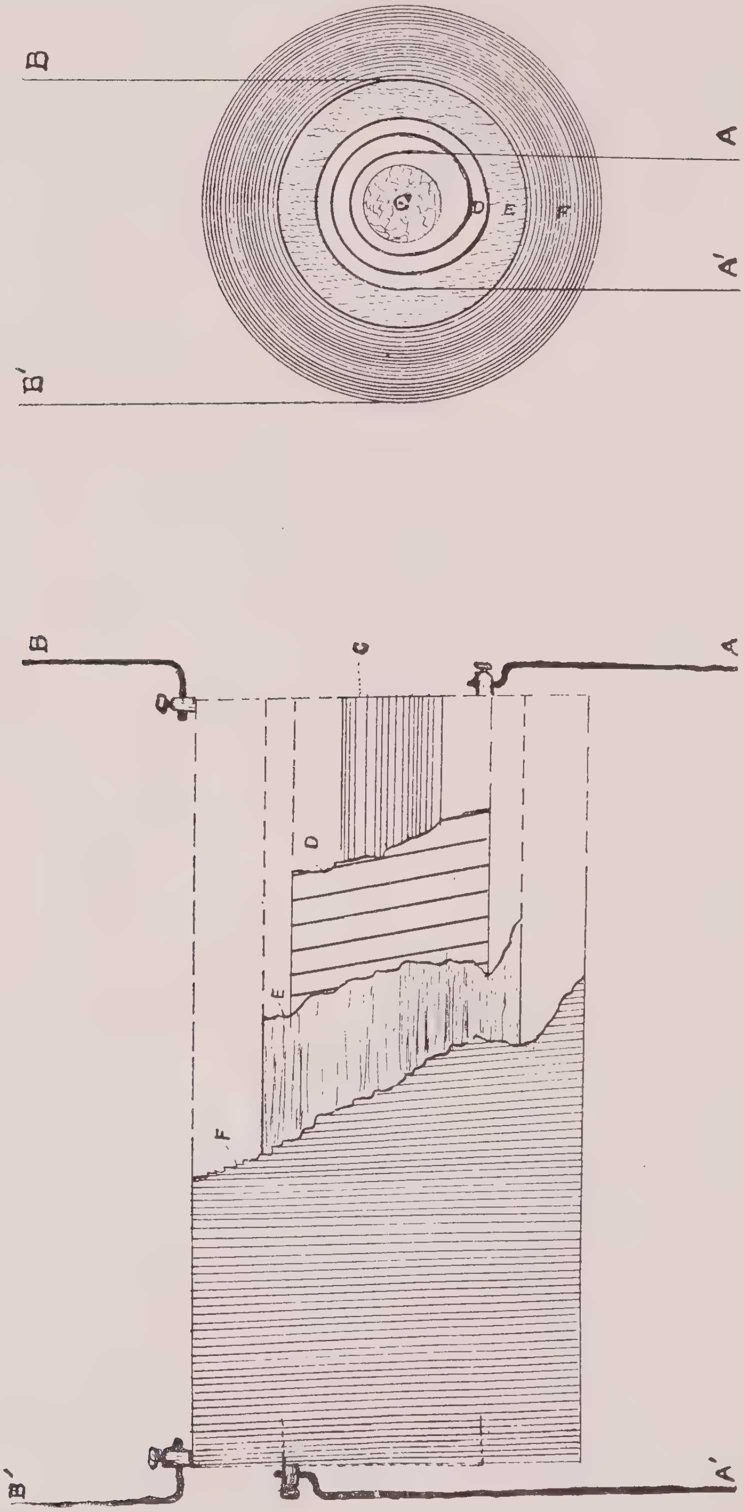


Fig. 11.—Diagrammatic illustration of the essential parts of an induction coil. *A′* and *A* are the terminals of the "primary coil." *D* represents the windings of the "primary" about the magnetic core *C*. The insulating medium between the "primary" and "secondary" is shown at *E*. The windings of the "secondary" coil are designated by *F*, and the "secondary" terminals by *B* and *B′*.

secondary coil is to the number of turns in the primary." For instance, suppose we have an induction coil with 10 turns of wire in the primary, and 100 turns of wire in the secondary. If we pass a current of 110 volts through the "primary," the voltage of the "secondary" current will be—

$$\frac{110}{10} \text{x} 100 = 1100 \text{ volts.}$$

Notwithstanding the great change in voltage, the wattage of the secondary current is the same as it was in the primary (except for a small loss due to internal resistance). This is not true, however, of the amperage. For example, if the primary current of 110 volts carries 5 amperes, its wattage would be 550. The wattage of the secondary current would also be 550, and since wattage equals amperes multiplied by volts, the amperage of the secondary current would be.

$$\frac{550}{1100} = \tfrac{1}{2} \text{ ampere.}$$

Thus it will be seen that as the voltage, or E.M.F., is increased in the before described manner, the amperage or current strength is decreased in equal ratio. It should be plain, therefore, that the original current running to the primary is not changed in actual value, but is simply transformed to a state or condition where it will do the special work required of it.

In our consideration thus far we have considered the manner in which an electric current may be transformed from a low to the high voltage necessary to energize an x-ray tube. We have not, however, named one important requisite of a current to be used for this purpose, namely, that the current must flow *continuously and in the same direction.*

In considering the manner of obtaining a current in

the secondary, we learned that such a current is produced by "making" and "breaking" the primary current. If a continuous current is to be kept flowing, we must utilize some instrument which will rapidly "make" and "break" the current in the primary circuit. Such an instrument is known as an "interrupter" and is essential to any induction coil.

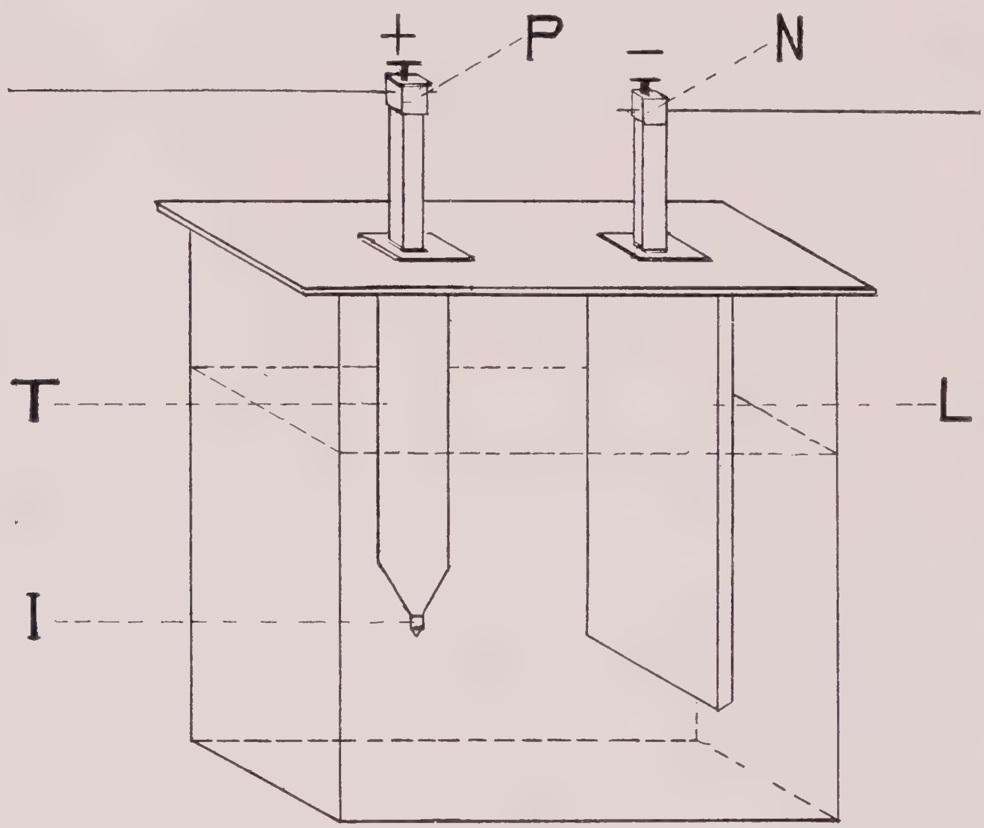


Fig. 12.—Diagram of the electrolytic interrupter. *P*, terminal of the positive electrode; *N*, terminal of the negative electrode; *T*, procelain sheath or tube covering the positive electrode; *I*, platinum point of the positive electrode; *L*, negative electrode constructed of lead.

There are two classes of these instruments, both of which utilize some automatic principle, and are known as "mechanical" and "electrolytic."

Mechanical interrupters, a simple illustration of which is the ordinary vibrator used on small coils, electric bells, etc., will rapidly make or break the primary current and thereby induce a fairly constant current in the secondary; but this form of interrupter has not been found to be so satisfactory for x-ray work as the electrolytic type.

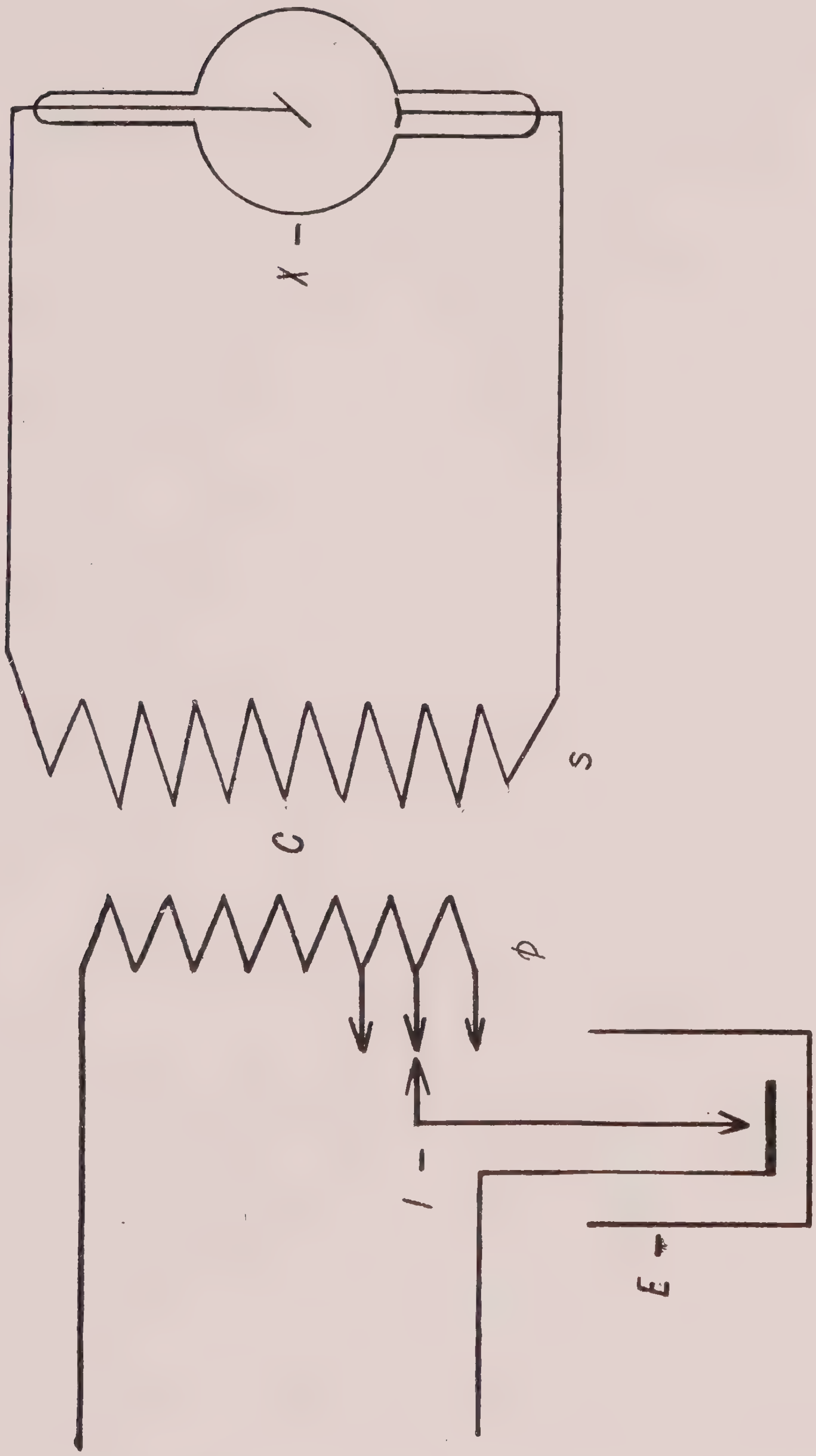


Fig. 13.—Diagram of the induction coil. *C,* induction coil; *P,* "the primary;" *S,* "the secondary;" *E,* electrolytic interrupter in circuit with the primary coil; *I,* rheostat and inductance control; *X,* x-ray tube connected to the terminals of the secondary coil.

Of the various forms of *electrolytic interrupters,* the Wehnelt type is the one most universally used. It consists of a large battery jar which is nearly filled with a solution composed of sulphuric acid one part and water six parts. Into this solution are introduced two electrodes. The negative electrode is constructed of lead and has a large surface exposed, while the positive electrode is contained within a porcelain or hard rubber tube extending down into the solution with only the tip or end of the electrode exposed. The tip of this electrode is usually made of platinum. (See Figs. 12 and 13.)

The electrolytic interrupter is connected in the primary circuit and operates briefly as follows: As the current passes from the platinum point (the positive electrode) through the solution to the negative electrode, by virtue of its chemical action upon the solution bubbles of gas are formed around the exposed platinum point. These bubbles act as a source of insulation and the current ceases to flow—"It is interrupted." At the instant it is interrupted, the bubbles are dispersed, the solution again comes in contact with the electrode, and the current is reestablished only to be broken again and so on, these changes taking place with tremendous frequency. With such an instrument the primary current may be interrupted from 60 to 30,000 times a minute. These interrupters are sometimes constructed with several platinum points which makes possible a greater amperage in the current without decreasing the rate of interruptions. For dental radiography, however, a single point interrupter will usually suffice, and at most, not more than a two point interrupter need be used.

The interrupter, then, serves the purpose of creating the magnetic impulses which keep a constant current flowing from the secondary. We should bear in mind, however, that the current produced by the "make" and

"break" are not currents of equal strength, the current produced at the "break" having much the highest value. The fact that this current is the strongest, and that the magnetic impulses come from the same direction (as the

Fig. 14.—Induction coil adapted for use in the dental x-ray laboratory.

induction coil is used on the direct current) it prevails over the weaker. Therefore the induced or secondary current which we use to energize the x-ray tube is the current which is created at the instant of the break.

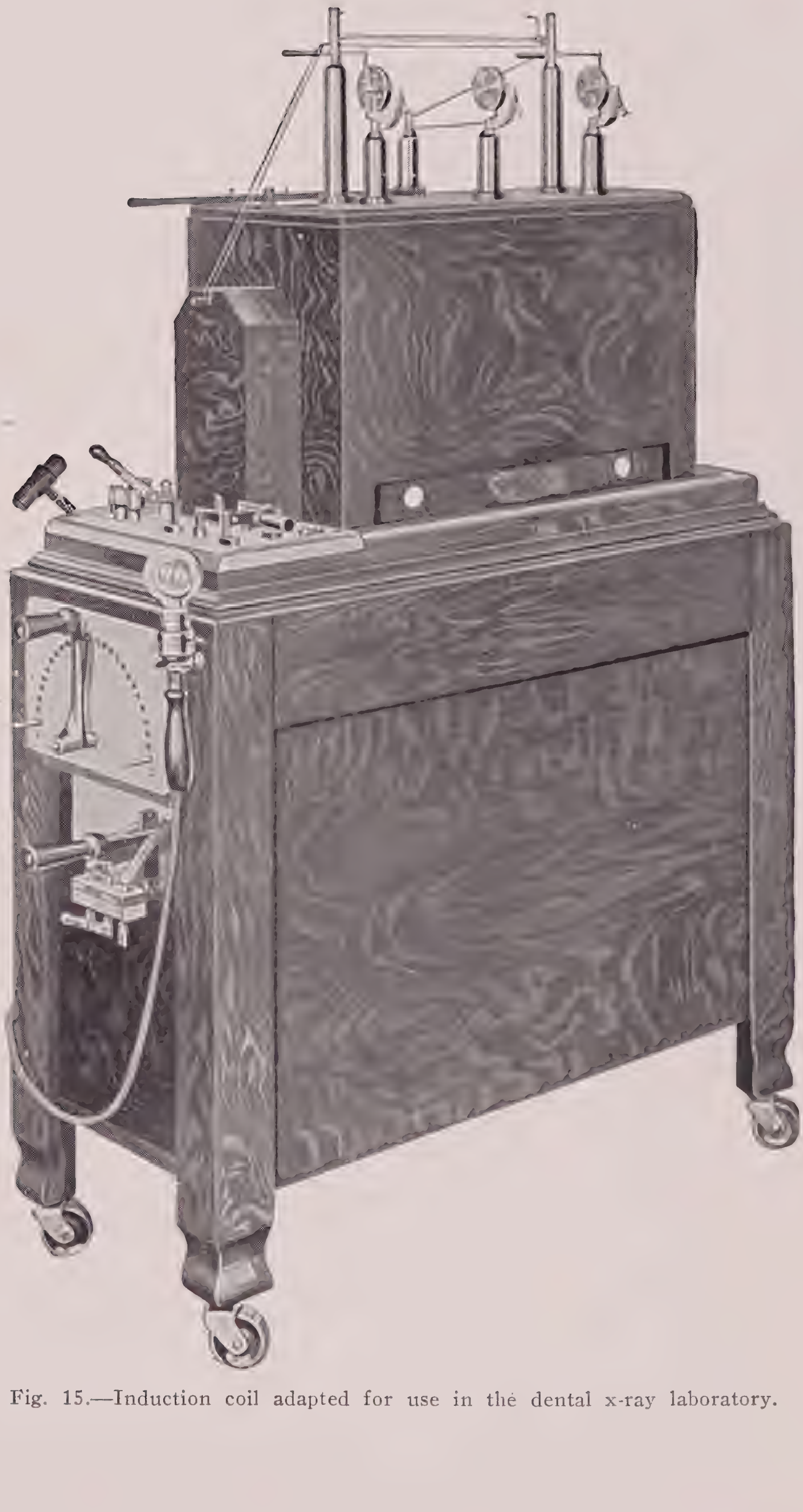


Fig. 15.—Induction coil adapted for use in the dental x-ray laboratory.

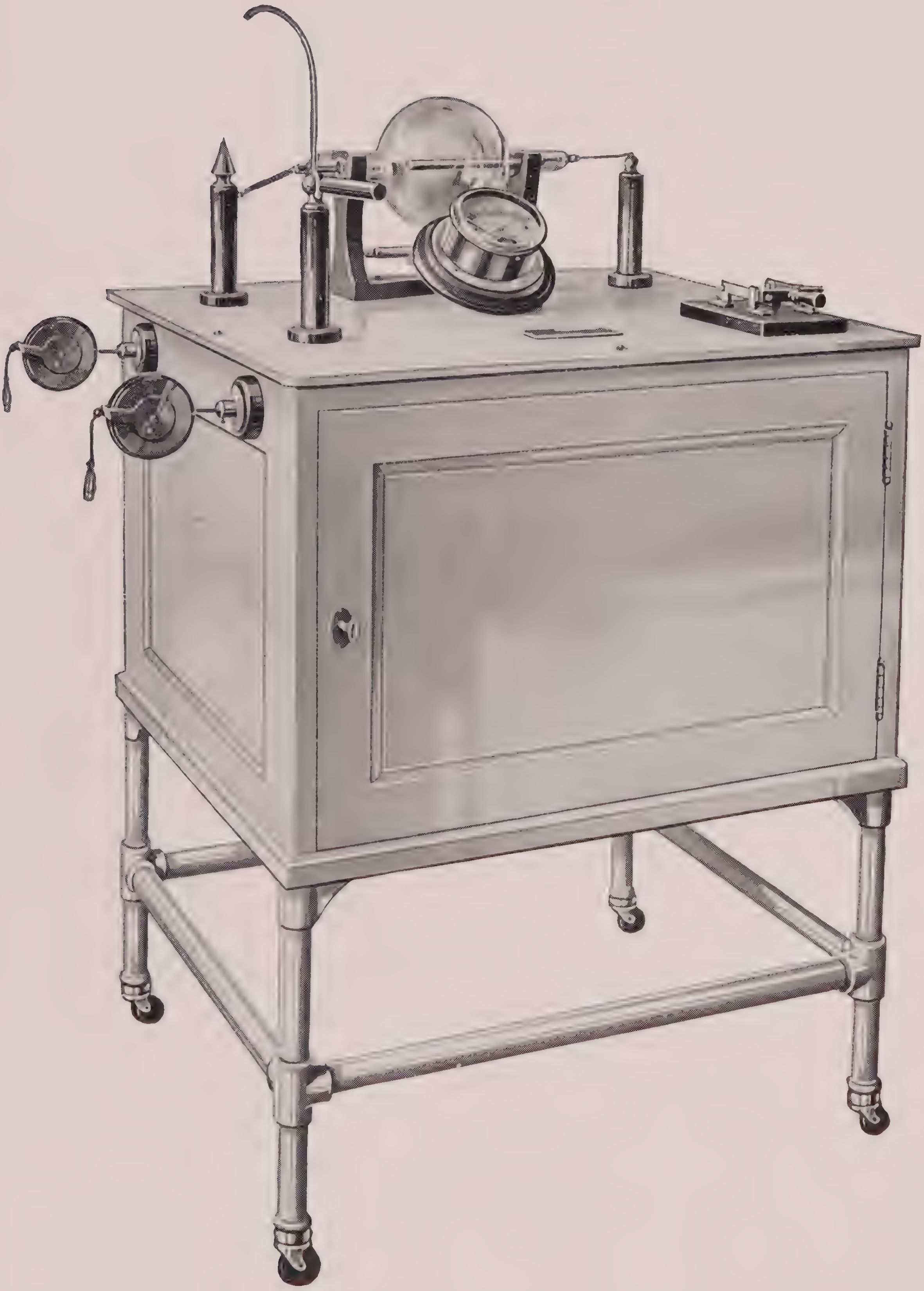


Fig. 16.—Induction coil adapted for use in the dental x-ray laboratory.

The other wave, or that created by the "make," is current in the wrong direction, and is called "inverse current." In some induction coils this inverse current is the source of much trouble, and where it is present to any appreciable extent, will result in blurred radiograms. It can be controlled, however, by the use of "valve tubes," or a "spark gap," arranged in series with the x-ray tube, the valve tube or spark gap serving the function of cutting out the weaker or inverse current, without interfering to any appreciable extent with the stronger current which is delivered to the terminals of the x-ray tube.

The induction coil is used on the direct current of 110 or 220 volts. Where only the alternating current is available, some means must be used to change the current from alternating to direct before it enters the primary circuit of the coil.

This change in the current can be accomplished by the use of "a rotary converter," of which several makes are available, or by a "chemical rectifier." These rectifiers generally consist of two electrodes immersed in a solution of the phosphate salts of potassium, sodium, or ammonium, one electrode being made of aluminum, and the other of lead, iron, or carbon. When working properly, the current will flow to the aluminum through the solution, but not away from it, thus cutting out one wave of the alternating current; or it is possible, by properly connecting up three or four jars containing the electrodes, to utilize both waves of the current.

Induction coils are usually rated as to power by the maximum width of the secondary spark gap; that is, the amount of distance the spark will jump between the secondary terminals. For example, a 12-inch induction coil is capable of producing a spark that will jump twelve inches of atmosphere. While these coils are made in va-

rious sizes, capable of producing a spark from six inches to forty inches in length, there is no particular advantage in using more than a 12-inch coil for dental radiography. (See Figs. 14, 15, and 16.)

Tesla, or High Frequency, Coil

The Tesla, or high frequency, coil differs considerably in construction from the induction coil, although many of its principles are the same (Fig. 17). In a way it is a double induction coil with the secondary of one coil acting as the primary of the other coil. An alternating current is utilized in the primary of the first coil and by means of the secondary of this same coil is stepped up to a high voltage. This "stepped-up" current is then carried to a condenser. As the current leaves the condenser, it is oscillating at a great rate of frequency and passes into the primary of the Tesla, or second, coil where it induces a current in the secondary of this coil. From the terminals of the last secondary, it is carried to the x-ray tube. The principles involved in this type of apparatus are shown in Fig. 17.

Like the current of the induction coil, the current from the Tesla coil is high in voltage and low in amperage, but unlike the current from the induction coil it is not unidirectional, but is alternating in character. For this reason, it is considered by some as being less desirable for radiographic purposes. However, this apparently objectionable feature is overcome by using an x-ray tube constructed in such a way as to cut out one wave of the current and thereby produce practically the same result as where a unidirectional current is used.

These coils have the advantage of being less cumbersome, require less space and are less expensive than the other form of apparatus, but they can not be depended upon to do the character of work that the powerful "in-

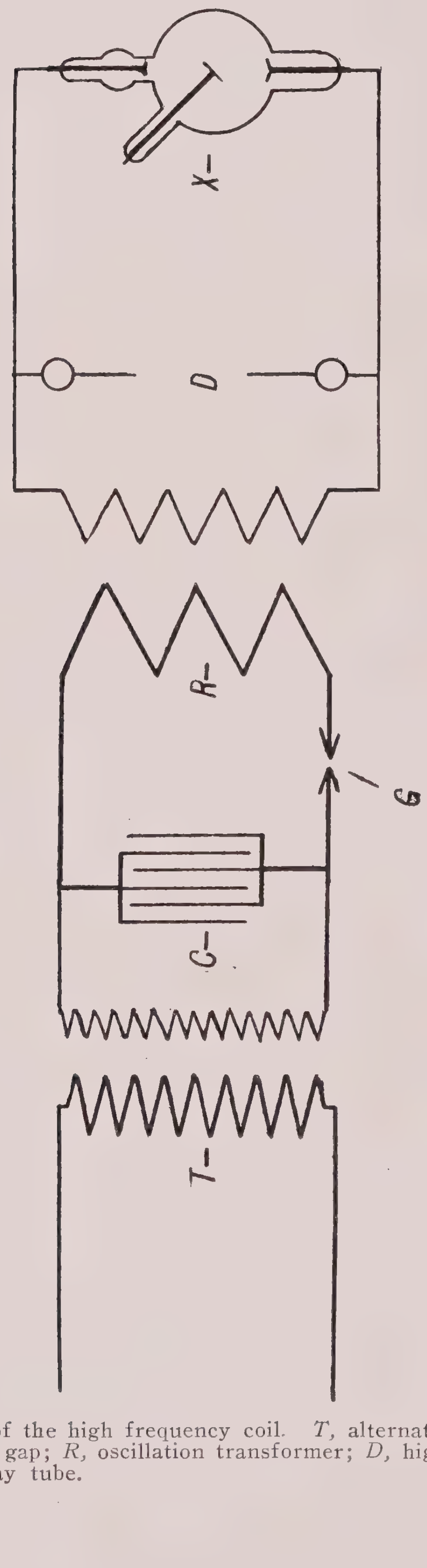


Fig. 17.—Diagram of the high frequency coil. *T,* alternating current transformer; *C,* condenser; *G,* spark gap; *R,* oscillation transformer; *D,* high tension discharge gap; *X,* high frequency x-ray tube.

duction coil" or "interrupterless transformer" will do. Notwithstanding this fact, this type of apparatus undoubtedly has a place in the x-ray laboratory of the dentist, and if constructed along proper lines can render splendid service. Three sizes of these coils are shown in Figs. 18, 19, and 20.

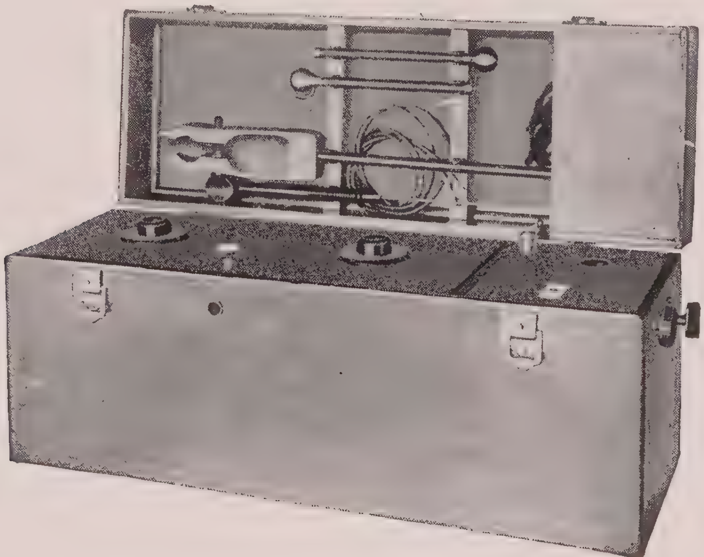


Fig. 18.—Small type high frequency coil.

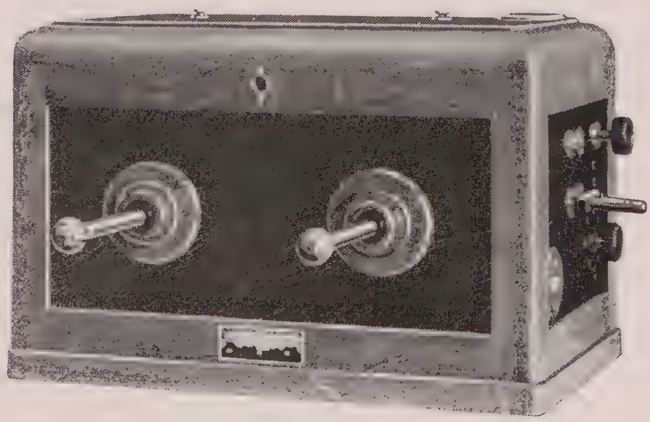


Fig. 19.—Medium-sized high frequency coil.

Interrupterless Transformer

The interrupterless transformer is the newest and by all means the most powerful x-ray machine made. Aside from controlling and measuring apparatus, it consists of three principal parts, a rotary converter, if direct current is the source of supply, or a synchronous motor if

the alternating current is the source of supply, a step-up transformer, and a rectifying switch.

Two types of these machines are made; viz., a direct

Fig. 20.—Large type high frequency coil.

current machine, and an alternating current machine, the underlying principles of which are shown in Fig. 21.

When used on the direct current, the rotary converter

is set in motion and generates an alternating current which is sent through the primary of the step-up transformer. This induces a current in the secondary of the proper voltage, but alternating in character. The rectifying switch then changes this current from an alternating

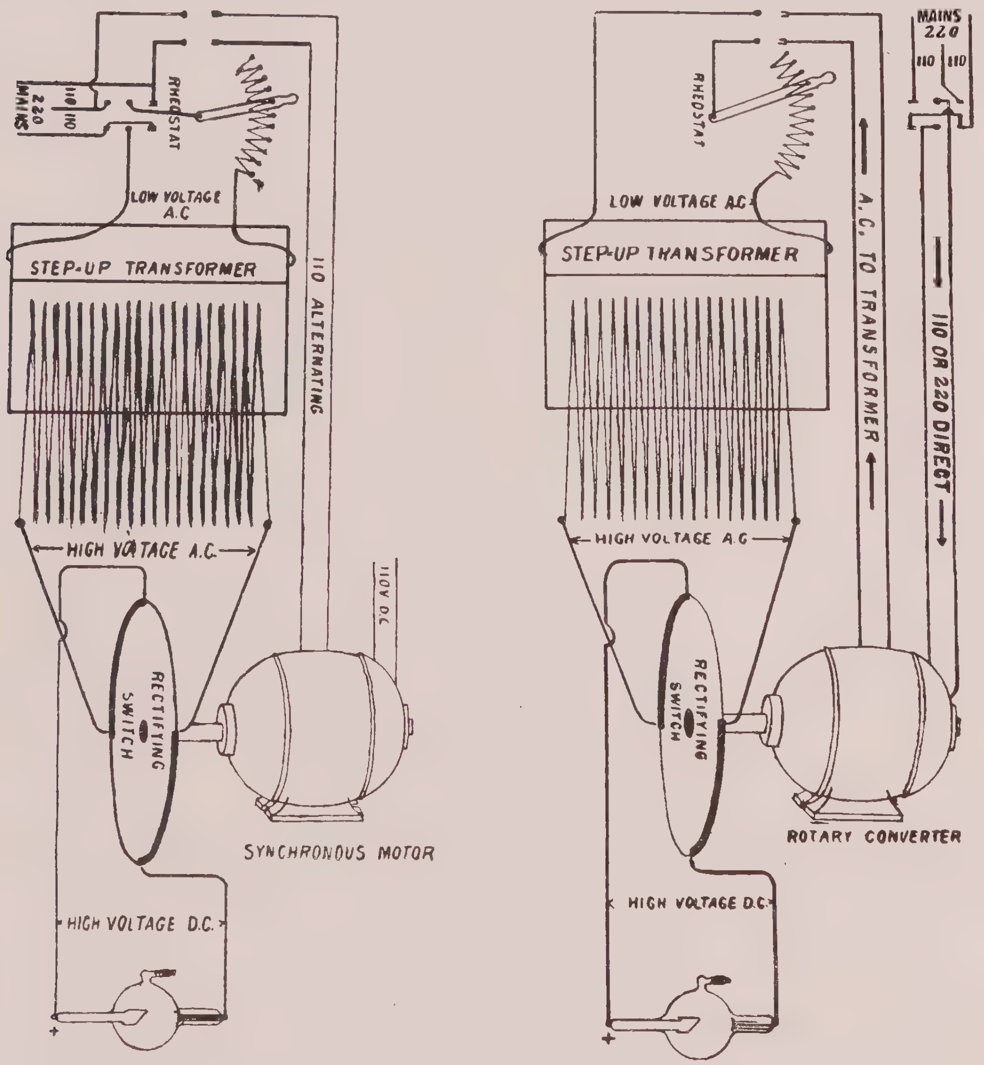


Fig. 21.—The working principles of the interrupterless transformer are here shown. The synchronous motor used to operate the rectifying switch of the alternating current machine may also be used as a rotary converter where the direct current is desired for other purposes in the laboratory.

to a direct current and as such it is delivered to the terminals of the tube.

The alternating current machine differs only from the direct current machine in that the alternating current is run directly into the primary of the step-up transformer. This induces a current in the secondary of proper voltage

but alternating in character. The rectifying switch then changes this high voltage alternating current to a direct current, and as such it is carried to the terminals of the tube.

The interrupterless transformer is, as stated before, the most powerful and efficient type of apparatus available for x-ray work. It is likewise the most expensive,—too expensive in fact to be considered for the x-ray lab-

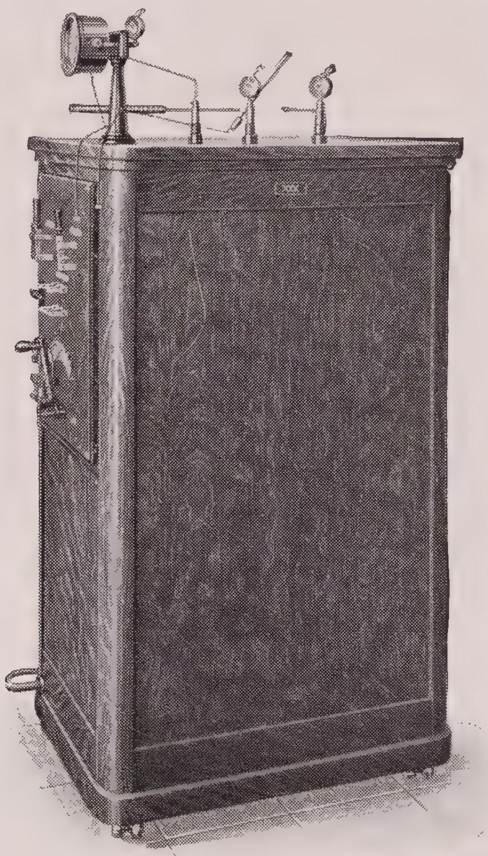


Fig. 22.—Interrupterless transformer adapted for use in the dental x-ray laboratory.

oratory of the average practitioner of dentistry, in view of the fact that with the induction coil and other less expensive apparatus such excellent results can be obtained.

The preceding remark, however, should not be construed as an argument against the interrupterless transformer. To the prospective purchaser who desires the very best, regardless of expense, or who expects to do a great deal of radiography, the initial expense should not

be the prime consideration, as oftentimes the most expensive things in the long run prove a matter of economy.

In conclusion, I would emphasize the fact that the char-

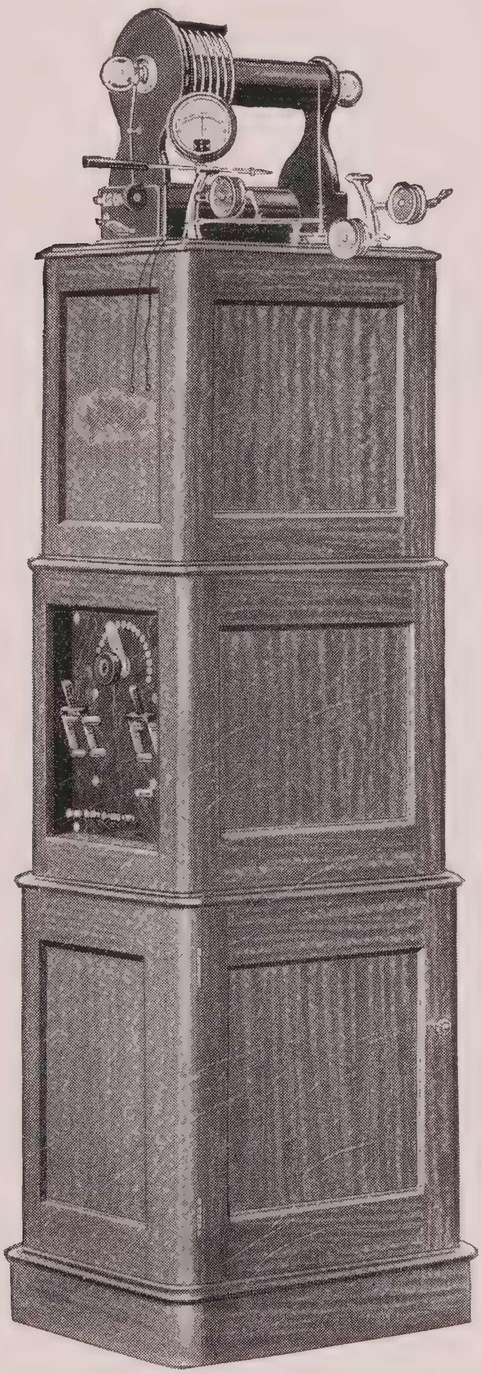


Fig. 23.—Interrupterless transformer adapted for use in the dental x-ray laboratory.

acter of the radiography which any physician or dentist is able to do, does not depend entirely upon the excellence of his laboratory equipment. Instances could easily be

Fig. 24.—Interrupterless transformer adapted for use in the dental x-ray laboratory.

cited where the best of equipment fails to produce the highest type of results, and vice versa, where unpretentious equipment in some hands has proved more than satisfactory. After all, the comparative degree of efficiency of the various type of x-ray machines must depend largely upon the judgment and skill of those who operate them.

In Figs. 22, 23, and 24 several interrupterless transformers adapted for use in the dental x-ray laboratory are shown.

CHAPTER V

REQUISITES OF THE DENTAL X-RAY LABORATORY

The requisites of a dental x-ray laboratory are not numerous but consist of—

1st—A so-called x-ray machine.

2nd—An x-ray tube.

3rd—An adjustable "tube stand" for holding the tube, which should include a "tube shield" made of leaded glass, serving as a means of confining the rays and as a source of protection to the operator, and a lead "compression diaphragm" and lead-lined "compression cylinder."

4th—A photographic darkroom.

As x-ray machines have already been discussed, let us now take up the others, in the order in which they have been given.

X-ray Tube

The x-ray tube is a thin glass bulb six or eight inches in diameter, having two elongations or stems projecting from the bulb opposite and in line with each other (see Fig. 25). One of these elongations has within it a sheet iron tube at one end of which is a block of copper, faced with platinum or tungsten, and set at an angle of 45 degrees. The other end of this sheet iron tube carries a platinum wire which is sealed into the glass at the end of the elongation and connected to a cap on the outside which serves as an electrical connection.

The other elongation carries a rod at one end of which is a concave aluminum reflector, the other end being con-

nected by means of a platinum wire sealed in the glass to a cap on the outside of the elongation, and also serves as an electrical connection.

The cancave reflector is known as "the cathode" and the metallic block opposite it and located upon the end of the sheet iron tube is known as the "target" or "anode." Above the anode and at an angle there is another stem projecting which carries a metallic terminal known as the "assistant anode."

This assistant anode has a platinum wire extending from it which is sealed into the glass and connected to a metallic cap on the outside of the tube. The outer terminals of the assistant anode and the anode are connected by means of a spiral spring.

Directly above the anode on the top of the tube there is a small chamber with an arm extending from it at right angles. This is known as "the regulating chamber." The arm extension of this chamber is filled with asbestos impregnated with chemicals, and arranged about or within a small metal tube from which a platinum wire extends, is sealed into the glass and connected to a metallic cap on the outside end of the chamber arm.

Before being finally sealed, the tube is pumped to a high degree of vacuum (about 1/100,000 part of an atmosphere), only enough air being left in it to afford a path for the passage of the electric current.

Three general types of tubes are made for radiographic work, all of which embody the same general principles but vary according to the type of the machine upon which they are to be used.

They are designated as follows:

1. The coil tube.
2. The transformer tube.
3. The high frequency tube.

Coil tubes and transformer tubes are similar in con-

struction but not in vacuum (see Fig. 26). Coil tubes are exhausted to a much higher degree of vacuum in order to lessen the tendency for inverse current, and give a high degree of penetration. The transformer tube is made comparatively low in vacuum as the current from the transformer is entirely free from inverse, and of such high voltage that the high vacuum is neither necessary nor advisable.

The high frequency tube differs slightly in construction from the coil and transformer tubes owing to the fact that the high frequency current is not unidirectional. Therefore, a means must be resorted to for cutting out or disposing of one wave of the alternating current. This is accomplished, as shown in Fig. 27, by placing the anode or target in the position occupied in the coil tube by the assistant anode except that it extends down to the center of the tube. Then by having what really amounts to two cathode terminals, only one of which is focused against the face of the anode, and the other into a funnel in the back of the target, almost the same effect is produced as results from a unidirectional current.

Connecting the Tube to the X-ray Machine

In connecting up the tube to a coil or transformer (Fig. 28), the anode terminal (A) is connected by means of a wire cord coming from a reel attached to the positive terminal of the machine (A'), and the cathode terminal (C) is connected in a similar manner to the negative terminal of the machine C').

A third wire cord is usually run from a reel (R') situated on the coil near the negative terminal to the cap on the regulating chamber (R). This third terminal on the coil has a spark gap between it and the negative terminal the length of which is adjustable (designated by S' and S).

Operating the X-ray Tube

When the current is started in the machine, it enters the tube at the anode and passes across the gap to the cathode, from which it is reflected back as the invisible cathode stream to strike a focal point on the target where the x-rays are produced and pass out through the walls of the tube (see Fig. 25).

With the passing of the current through the tube, it should light up in a characteristic manner, forming two hemispheres which have a definite line of demarcation.

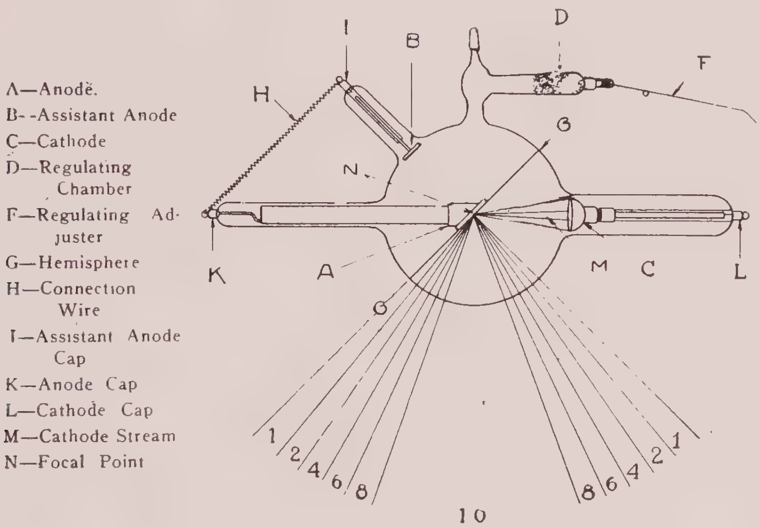


Fig. 25.—Diagram of an x-ray tube.

The hemisphere in front of the target which is the active hemisphere, is evidenced by a green fluorescence, the shade of coloring depending upon the degree of vacuum of the tube. The fluorescence of a highly exhausted tube will be a light yellowish green, a tube low in vacuum will show a bluish green, while a medium tube will be an intermediate green.

For dental radiography, a fairly high tube is indicated and its vacuum should be kept as nearly uniform as possible. This is made possible by utilizing the third terminal from the x-ray machine. By placing the spark gap of this terminal about three or four inches from the nega-

tive terminal of the machine, the current will, when the vacuum of the tube gets high enough to resist its passage, pass over the gap, down the third terminal wire

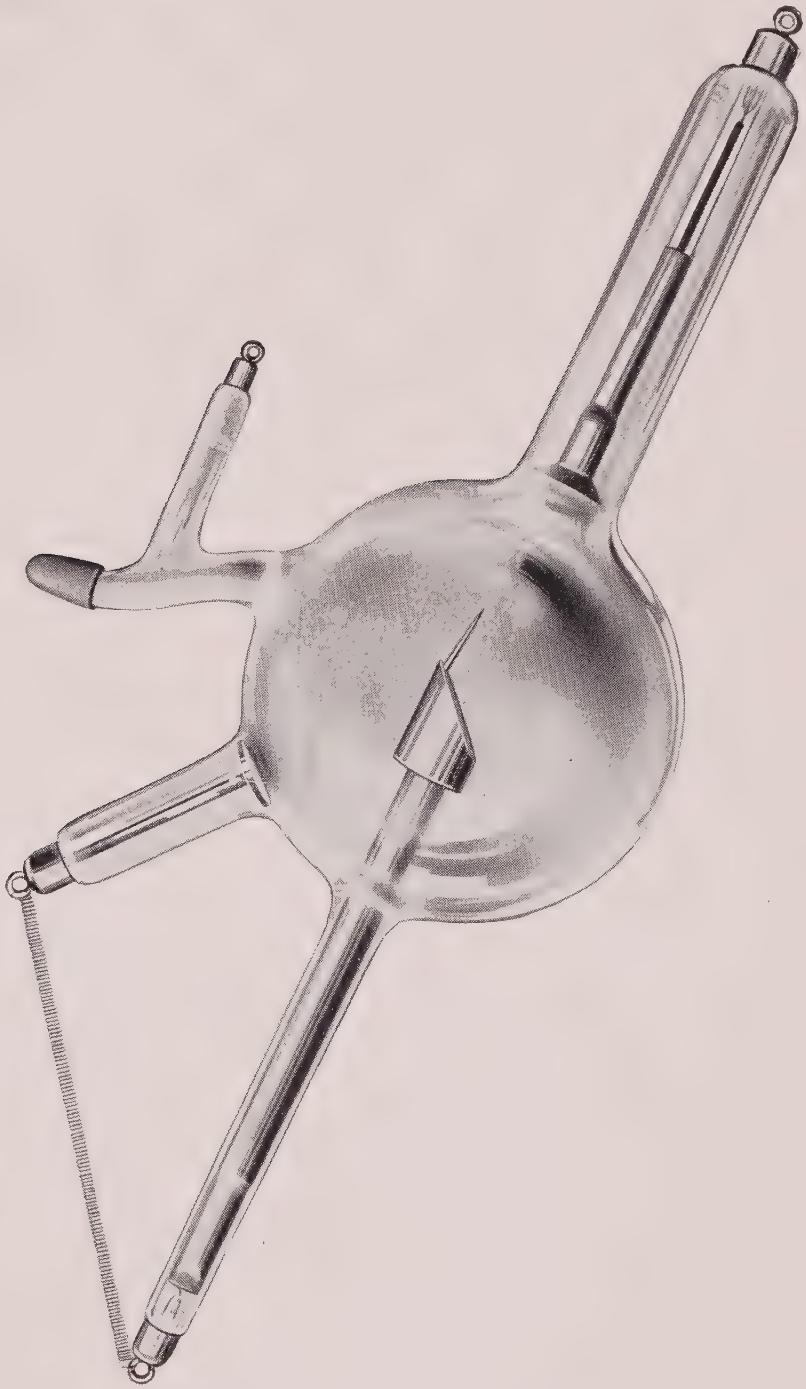


Fig. 26.—The coil or transformer tube.

into the regulating chamber where by heating the asbestos it will liberate gas and thereby reduce the vacuum of the tube.

In addition to the general types of tubes already described, there are certain specialized forms of tubes which

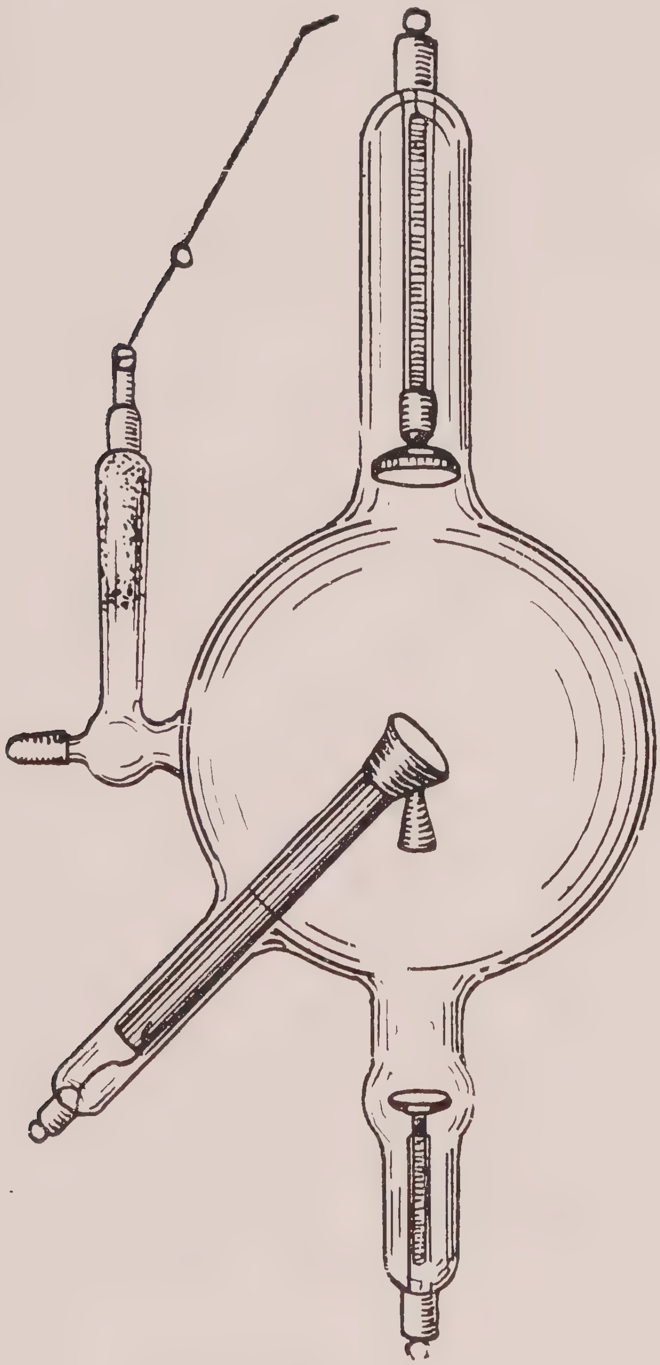


Fig. 27.—The high frequency tube.

are highly useful, and fast becoming popular. Of these, the "hydrogen tube" and the "Coolidge tube" are, by far, the most important.

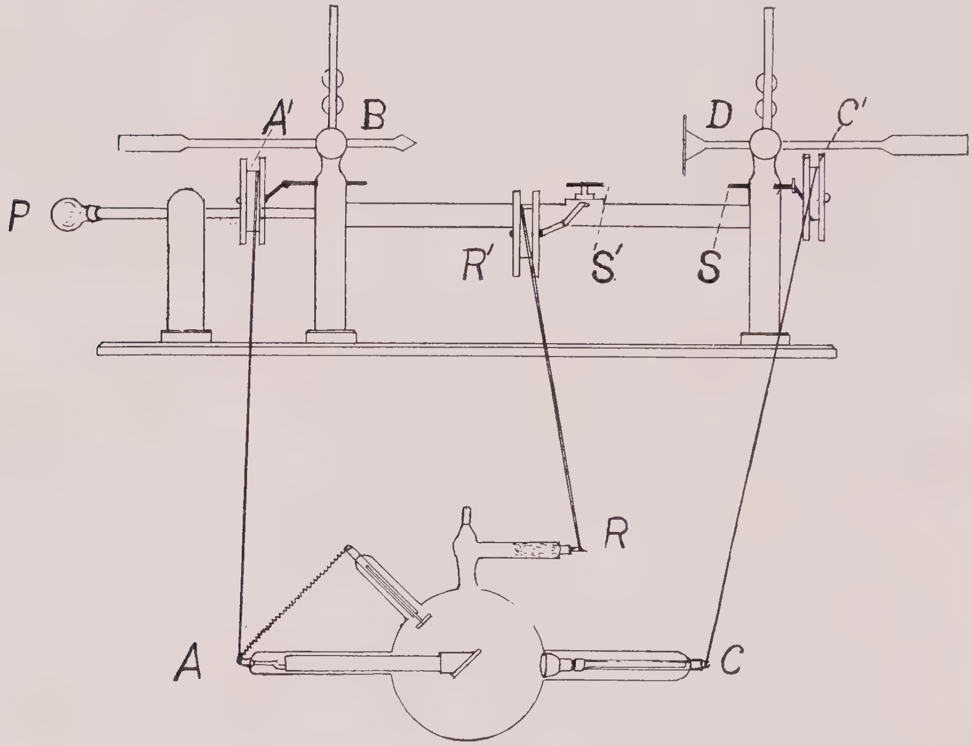


Fig. 28.

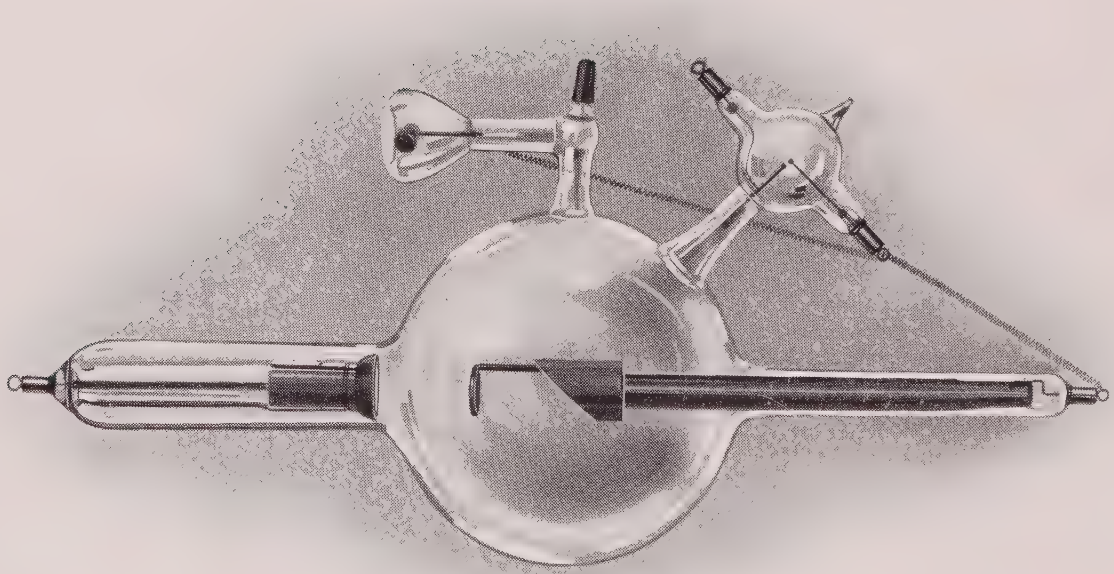


Fig. 29.—The hydrogen tube.

Hydrogen Tube

The hydrogen tube, shown in Fig. 29, differs from the ordinary gas tube in that in addition to having the reducing feature, in common with other tubes, it has the added advantage of having a raising device. This means that the hydrogen tube may be raised or lowered, at will. As the name implies, this tube contains hydrogen, which is greatly responsible for its unusual flexibility.

It is claimed for this tube that it has a slightly greater penetration than other tubes for a given parallel spark

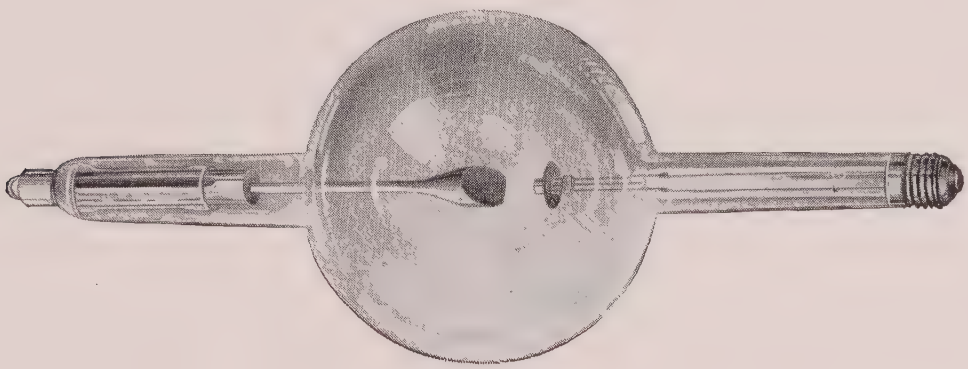


Fig. 30.—The Coolidge x-ray tube.

length. The target is made of tungsten, and the cathode is protected in the same manner as the tubes already mentioned.

Coolidge Tube

The Coolidge tube, shown in Fig. 30, is radically different in design from the other tubes already described, and is different in operation, in that it is energized by two independent currents, one of high voltage, and the other of low voltage. For this reason, certain auxiliary apparatus must be used with it, in addition to the x-ray generator. This auxiliary apparatus consists of a low voltage transformer and regulator, and an insulated stand or shelf for holding the transformer, and an ammeter. The low voltage current serves the purpose of

heating electrically a spiral filament of flat, closely wound tungsten wire located within a cylinder on the cathode. This electrically heated filament serves the important function of controlling the milliamperage of the current passing through the tube. The higher the filament temperature, the larger the number of milliamperes will flow through the tube and hence the shorter will be the exposure required.

This tube is fast becoming popular, due to the fact that it is rugged of construction, will stand hard and continuous service, and because of its ease of control, will give uniform results.

Tube Stand

The tube stand, which serves the purpose of holding the tube, should be sufficiently heavy to support it against motion and vibration, and should be sufficiently adjustable so that the tube can be raised or lowered, or placed at any desired angle. Its base should be mounted upon casters so that it may be moved with ease. Such a tube stand is shown in Figs. 31 and 32.

Tube Shield, Compression Diaphragm, and Compression Cylinder

The tube, tube stand, tube shield, compression diaphragm and compression cylinder, when adjusted for work, as shown in Figs. 31 and 32, really comprise a single piece of apparatus. Bearing in mind the fact that the x-rays pass out in every direction from the face of the anode, or target, (see Fig. 33-*A*) which is situated in the center of the tube, it is necessary, if the clearest possible shadows are to be produced, to use only those rays that have the same general direction and that have an equal amount of penetration. Now it is known that the most rapid and effective rays are those that pass out at

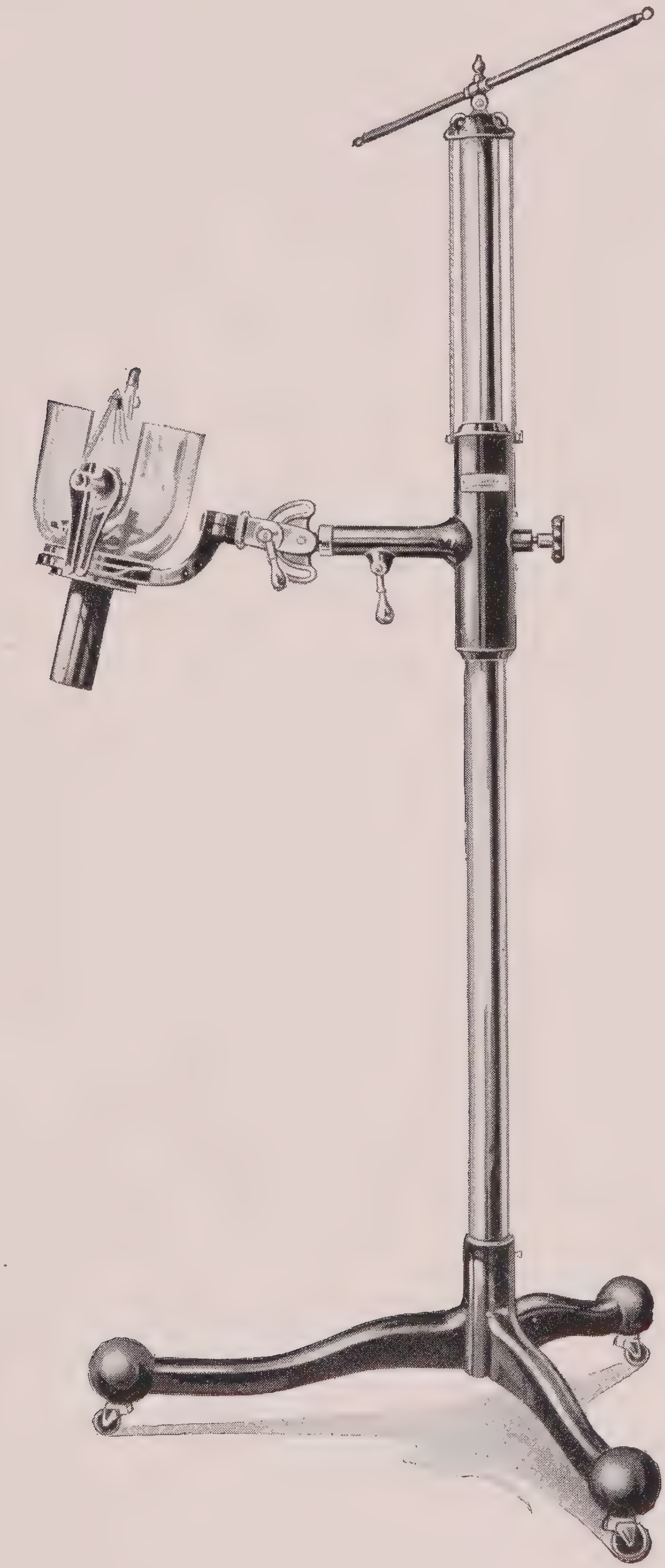


Fig. 31.—The tube stand.

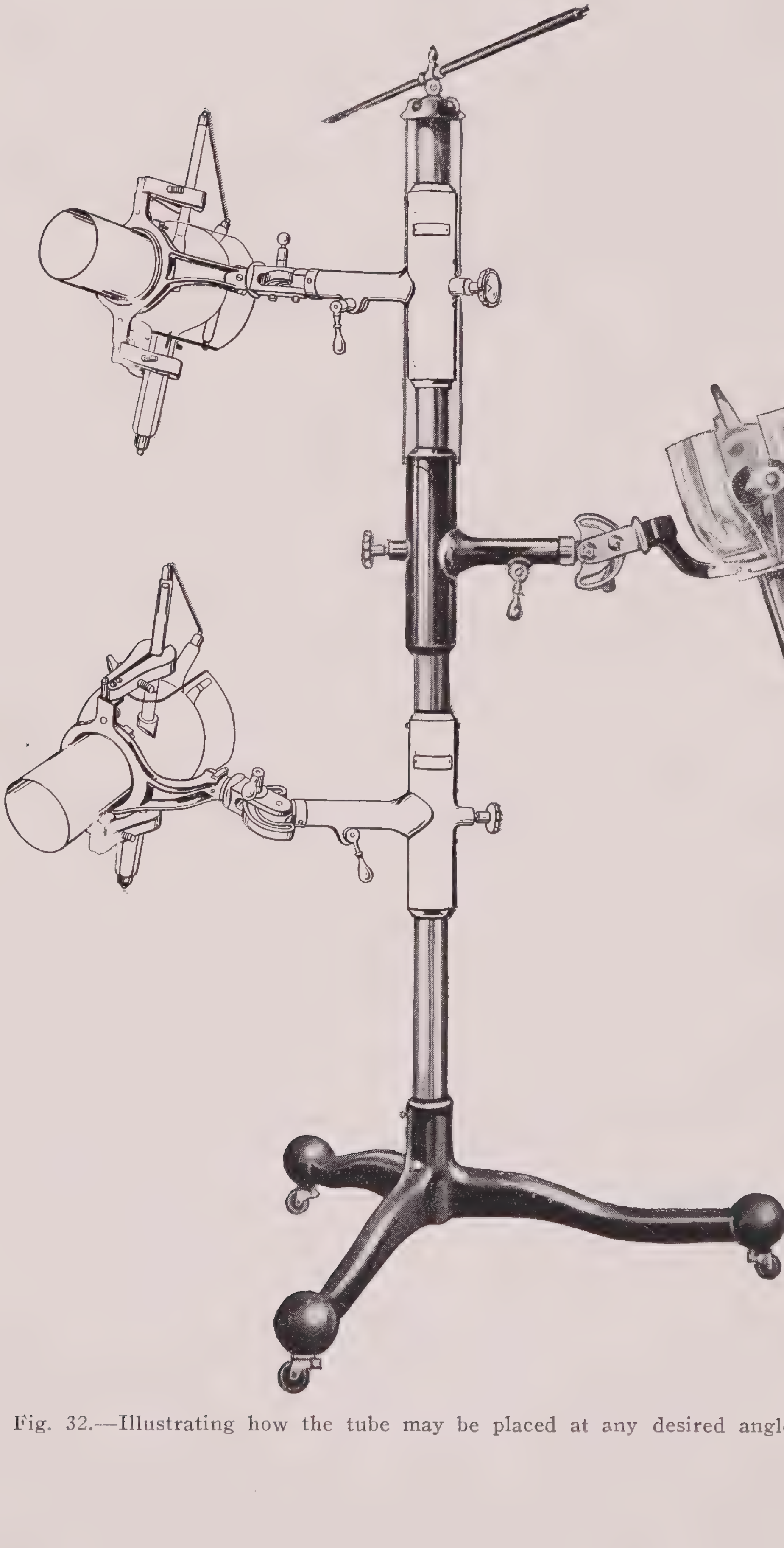


Fig. 32.—Illustrating how the tube may be placed at any desired angle.

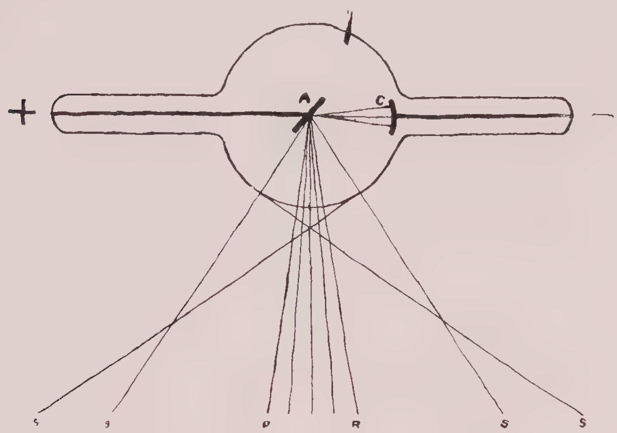


Fig. 33-*A*.

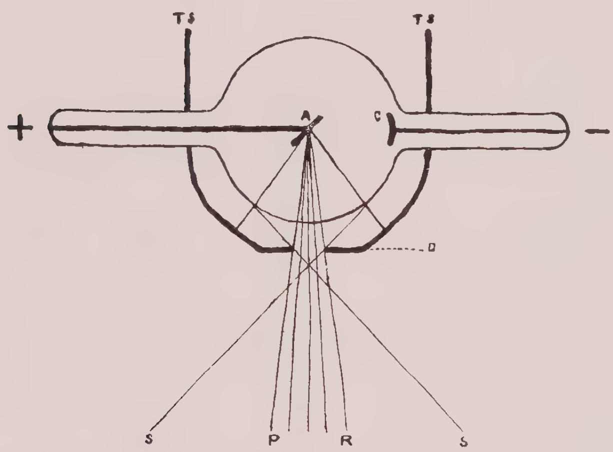


Fig. 33-*B*.

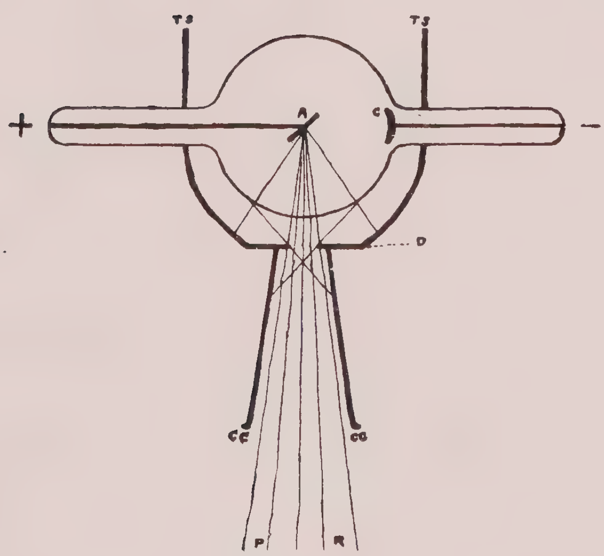


Fig. 33-*C*.

right angles from the cathode stream designated by *PR*. Inasmuch as we desire to use *these rays, and these rays only,* in casting our shadows, we must establish some means of preventing the other rays (*S,S,S,S*) from escaping from the immediate area surrounding the tube, and this is accomplished by means of the tube shield, compression diaphragm, and compression cylinder.

The tube shield (Fig. 34), a sectional diagram of which is shown in Fig. 33-*B* by *TS* is made of leaded glass, there being a sufficient amount of lead in the glass to

Fig. 34.—Leaded glass tube shield.

prevent ordinary rays from passing through it. The compression diaphragm makes up the floor of the tube shield (*D*), and is constructed of sheet lead with an opening of the proper size to allow the desired rays to pass through. The compression cylinder (*CC*) (Fig. 33-*C*) is made of aluminum with a lead lining that absorbs any secondary rays that have succeeded in passing through the diaphragm. It should be apparent to anyone that with this apparatus, the only x-rays that succeed in leaving the immediate area of the tube are those that are used to cast the shadows of the parts desired, which is

of great importance, not only in obtaining radiograms that are sharp and clear and uniform, but also to the health of the operator and others associated with him in the office.

Arrangement of the Apparatus in the Office

If dental x-ray equipment is desired, the question naturally arises, "Where can the necessary apparatus be

Fig. 35.—A convenient manner of arranging the necessary apparatus when not in use.

placed?" While a separate room is desirable, it is by no means necessary, as the ordinary operating room of "healthy size" can be made to accommodate it.

The coil or transformer, and the tube stand can be placed against the wall at the left of the room, while the tubes can be hung in a suitable rack upon the wall where they will be out of harm's way (Fig. 35). Arranged in this manner, x-ray apparatus is not in the way, and is accessible for use at any time.

The dental chair with its multitude of adjustments serves an important purpose in the dental x-ray laboratory, for the patient must be supported in such a manner as to be able to hold perfectly quiet during the time the exposures are made. Owing to the stability of the chair and its many adjustments, it will not only serve this purpose, but is preferable to having the patient lie upon a table which has been the method employed by many radiographers in the past.

Photographic Darkroom

Thus far we have discussed all but one of the requisites of the dental x-ray laboratory; viz., the photographic darkroom. This is a very important requisite, and anyone attempting to do radiography without it is greatly handicapped. It need not be large or elaborate, and running water is not absolutely essential, although it is an advantage. A closet 3½x5 feet will suffice if nothing better is available. A broad shelf should be placed at one end to hold the developing trays and other photographic accessories.

With a darkroom always available, the dental radiographer is able to develop his plates or films immediately, profit by their findings, or, in case they do not come out satisfactorily, make others without subjecting the patient to the inconvenience of another appointment.

Where limited space precludes the possibility of a regular darkroom, a developing cabinet, or so-called "portable darkroom" may be utilized. (See Fig. 36.) Such a cabinet may be placed upon a small table or attached to the wall at the proper height from the floor. It should be large enough to contain the necessary developing trays and other photographic necessities. The front panel should be hinged so as to permit easy access to the interior for the arrangement of the trays, solutions and

for their removal after development. The ruby lamp for lighting the interior should be an integral part of the cabinet and the "observation window" at the top should be so placed that the operator can have an unobstructed view of the interior. This window must be covered with ruby glass, and around it should be constructed a shield

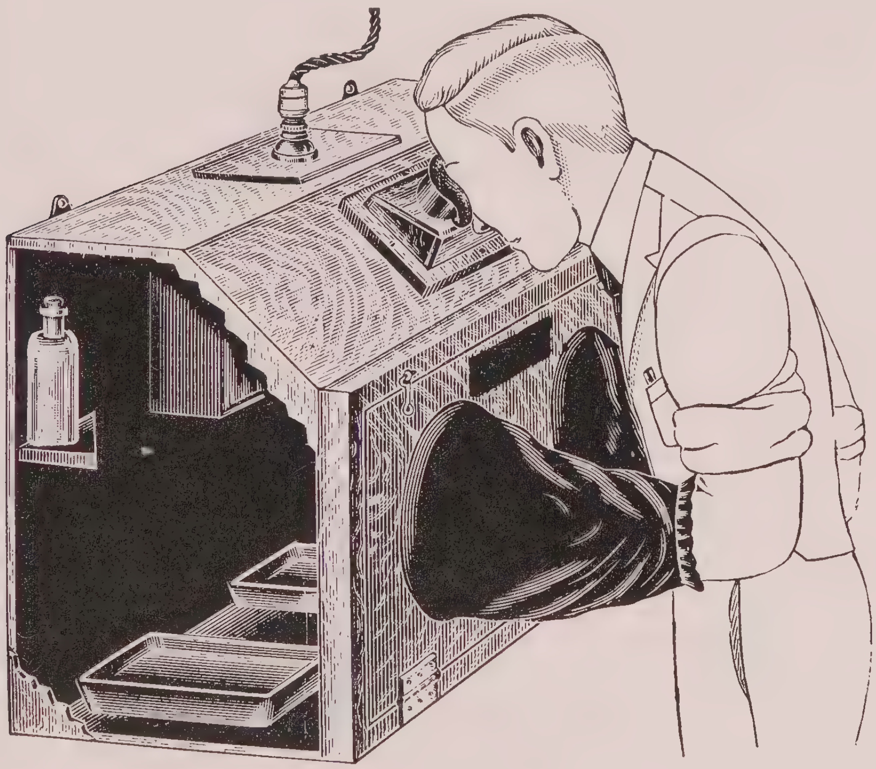


Fig. 36.—The portable darkroom.

which will shut out all outside light while the operator is looking into the cabinet.

With the portable darkroom, plates and films may be satisfactorily developed, but the process can not be carried with the same degree of comfort as where "a regular darkroom" is available. Therefore, any dentist intending to do any considerable amount of radiography can well afford to go to the trouble and expense of constructing a darkroom which will be comfortable, and contain all the conveniences.

CHAPTER VI

TECHNIC OF DENTAL AND ORAL RADIOGRAPHY

Having discussed the requisites of the dental x-ray laboratory, let us now proceed to a consideration of their application in the actual work of radiography.

The very nature of the structures with which we concern ourselves, their gross as well as minute anatomy, renders them somewhat difficult to radiograph, and necessitates a refinement of technic greater than that demanded for most of the other portions of the human anatomy. It would, therefore, seem obvious that an accurate knowledge and anatomic appreciation of the structures of the oral cavity and associated organs and structures is the first requisite for successful dental and oral radiography.

We should keep in mind the fact that radiograms are shadow pictures, and that the effect produced by the x-ray upon the photographic plate is but a shadowgraphic representation of the tissues through which the rays have passed. We know that this ray penetrates all matter in inverse ratio to its mass or density, and therefore the shadow picture which is left upon the photographic plate is simply a record of the varying density of the tissues through which the rays have penetrated.

The x-rays are particularly applicable to the dental and oral structures, owing to the fact that these structures differ enough individually in degree of density to permit of their appearing in a characteristic manner upon the photographic plate. For instance, it will be noted upon the examination of a dental radiogram, that metallic fillings appear as white masses, and root fillings as some-

what less dense lines. The enamel and dentin are next in density, and root canals show plainly as dark channels in the dentin, while the alveolar process and maxillæ show their fine uniform cancellous structure in various degrees of density depending upon their thickness.

As a tooth is much more dense than the bony structures of the jaw, any anomaly of form, size or position in the jaws is easily discernible even though it occupy a position far from what might be expected; as for instance, impacted molars, teeth in the antrum, etc.

Due to the fact that the structures within the field of our specialty have a characteristic appearance under normal conditions, any alterations or change in these structures is at once evident upon the plate. We thus are afforded a means of studying *intra vitam* the gross pathology of the structures of the oral cavity.

I would again emphasize a point previously made; viz., that a radiogram is not a photograph, but a shadow picture which is produced by using the x-ray as the source of illumination and the photographic plate as a screen for recording permanently the shadows cast.

Therefore, in making radiograms, we must adhere to the same rules which apply in making correct shadows with ordinary light. If correct shadows are cast, a certain definite relationship must exist between the source of illumination, the object, and the screen. Any change or variance in this relationship will result in a changed image. A simple experiment will suffice to illustrate to a beginner the truth of this statement.

Use a piece of ordinary white writing paper as a screen and hold it about two feet away from a lamp, and place your hand or any other small object, midway between the lamp and the improvised screen, and observe the shadow cast. You will note, first, that it is very much enlarged; and, second, that it is very faint and indistinct. Now,

slowly move the object toward the screen. As it approaches, the shadow becomes more distinct and smaller until at length when the object is almost touching the screen, the shadow will be good, black and distinct, and of practically the exact size of the actual object. It will also be found that the shadow can be altered by changing the position of the light, that is, moving it toward the object or away from it, by lowering it below the level of the object or raising it higher than the object; or by moving it to the right or to the left. Eventually, however, a point can be found which will cause the shadow to assume its most correct proportions as well as its sharpest outline. When this point is established, the light rays will be traveling in a perpendicular direction to a plane which lies midway between the plane of the object and the plane of the screen, and the light will be placed at what we call the proper focal distance.

Applying the laws deduced from this simple illustration of shadow making to radiography, we learn, first, that the closer we can bring the photographic plate to the tissues we wish to show, the clearer and sharper will be the resulting radiogram; second, that the x-rays in passing through the tissues, must travel perpendicularly to a line which lies midway between the plane of the tissues desired and the plane occupied by the photographic plate; and third, that the source of the x-ray production (the target of the tube) must be placed at a proper focal distance.

In order to obtain a radiogram of any portion of the body, it is necessary to have a photographic or x-ray plate, or film (properly prepared so as to exclude all light and moisture), placed in such a position that the rays passing through the structures desired, will register their shadows with the least amount of distortion possible upon the plate.

In securing shadowgraphic representations of the dental and oral structures, two general methods of procedure are open to us, each of which has its values and special indications. These are known as the ''inta-oral'' and ''extra-oral'' methods.

With the first, only small films are used which are placed within the month opposite the area to be radiographed, and held in position either by means of a tray or film holder, or by the assistant, or better still, by the patient exerting slight pressure with the finger. This method is indicated where radiograms of *small areas only* are desired, as, for instance, two or three of the teeth, with the adjacent alveolar process.

With the other method of procedure mentioned; viz., the ''extra-oral'' method, large plates or films are used and the areas desired are brought in as close contact as possible with the plate by pressing or resting the face against it. The x-rays are then passed through the structures from the other side of the skull, and oftentimes must pass through the entire face or skull, in transit.

When using this method, large areas may be radiographed, which in some instances will embrace the lateral halves of both the upper and lower jaws from the cuspid region anteriorly to the angle of the jaw posteriorly, and from the floor of the orbit above to the inferior margin of the mandible below. In fact, it is possible by making several exposures to obtain in detail a shadowgraphic representation of the dental apparatus *in toto*, as well as its associated organs and structures, the nasal cavity and pneumatic sinuses, the maxilla and the mandible.

It should be apparent to anyone that the first method greatly reduces the possibilities of the x-ray. Both methods have their advantages and neither should be discarded in favor of the other.

Intra-oral Method

We shall first discuss the intra-oral method by which small areas are radiographed. First of all, the patient should be placed in a comfortable position, *and the head supported so that it may be held perfectly still.* After the tube has been tested out and the proper degree of vacuum established, the tube stand (complete with the

Fig. 37.—The patient can hold the film in position against the upper teeth by exerting slight pressure with the thumb.

other apparatus before described) is moved to a position where the rays coming from the tube, through the compression diaphragm and cylinder can be made to pass through the desired areas and cast their shadows upon the small film within the mouth (Fig. 37).

In using this method upon the upper teeth, the greatest care must be exercised if the shadows produced are free from distortion, for the film must be held within the upper arch against the lingual side of the teeth and the palate, and must occupy a position which is in a different

plane from that occupied by the roots of the teeth. Whenever it is necessary to direct the rays upon structures that lie at an angle with the plate or film, correct shadows may be obtained by adhering to the following rule: *"Bi-*

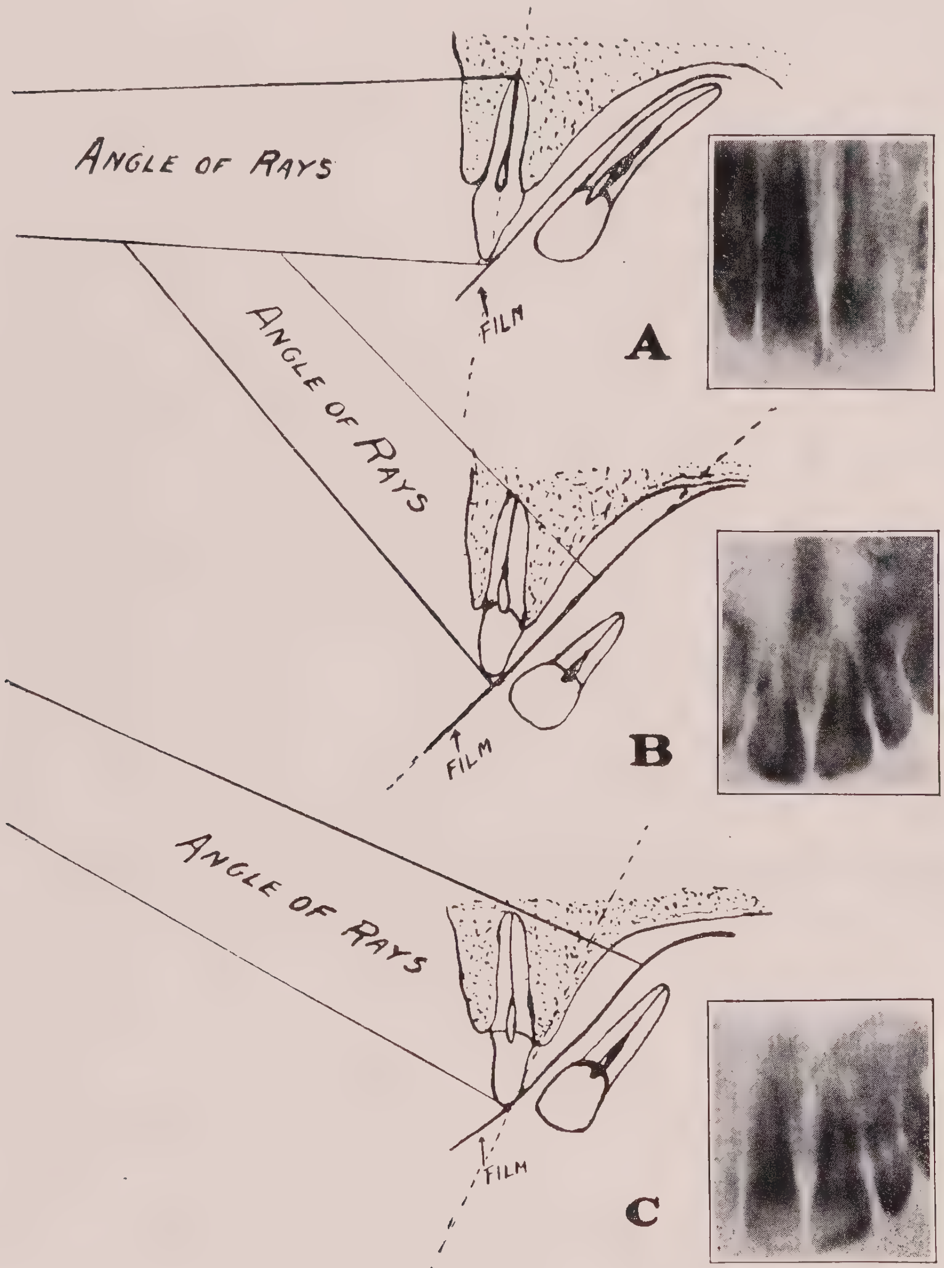


Fig. 38.—Correct and incorrect technic.

sect the angle made by the plane of the object, and the plane of the film, and direct the rays so that they will fall perpendicular to this bisected plane."

Failure to adhere strictly to this rule is one of the

most common causes of partial or complete failure in producing true shadowgraphic representations of the dental structures. For instance, if the rays are directed from too low a source, the shadows will be lengthened, or if they be directed from too high a source, the shadows will be foreshortened, the amount of elongation or foreshortening being in direct proportion to the amount of deviation from the proper focal point.

The importance of adhering strictly to this rule is graphically shown in Fig. 38,* where an upper central incisor and the adjacent teeth are radiographed. In the upper picture (*A*) the rays are passing in from too low a source with the result that the image imposed upon the film is lengthened to the extent that the resulting radiogram is useless. In the center picture (*B*) the rays are coming from too high a source, the result being a shortened image. Such a radiogram has but little value and in many instances would prove very misleading. In the lower picture (*C*) the rays are passing in at the correct angle; viz., they are directed perpendicularly to a plane which lies midway between the plane of the teeth desired and the plane of the film. The result is a radiogram in which the images of the teeth desired are imposed upon the film in their correct proportions.

It will be noted upon a close examination of this last radiogram (*C*) that an abscess is present upon the root of the right central incisor. By examining the other radiograms (*A* and *B*) it will be seen that this condition is not apparent in them, which lends emphasis to the importance of an exact technic.

The technic illustrated (by C of Fig. 38) is indicated for all of the upper teeth. Occasions may arise, however, where it will not suffice for the upper molar teeth owing to the fact that the buccal roots and the lingual roots may

*Technic of Dr Weston Price.

diverge to the extent of assuming different planes. In this event, it may be necessary to make more than one radiogram, if information of an exacting character is de-

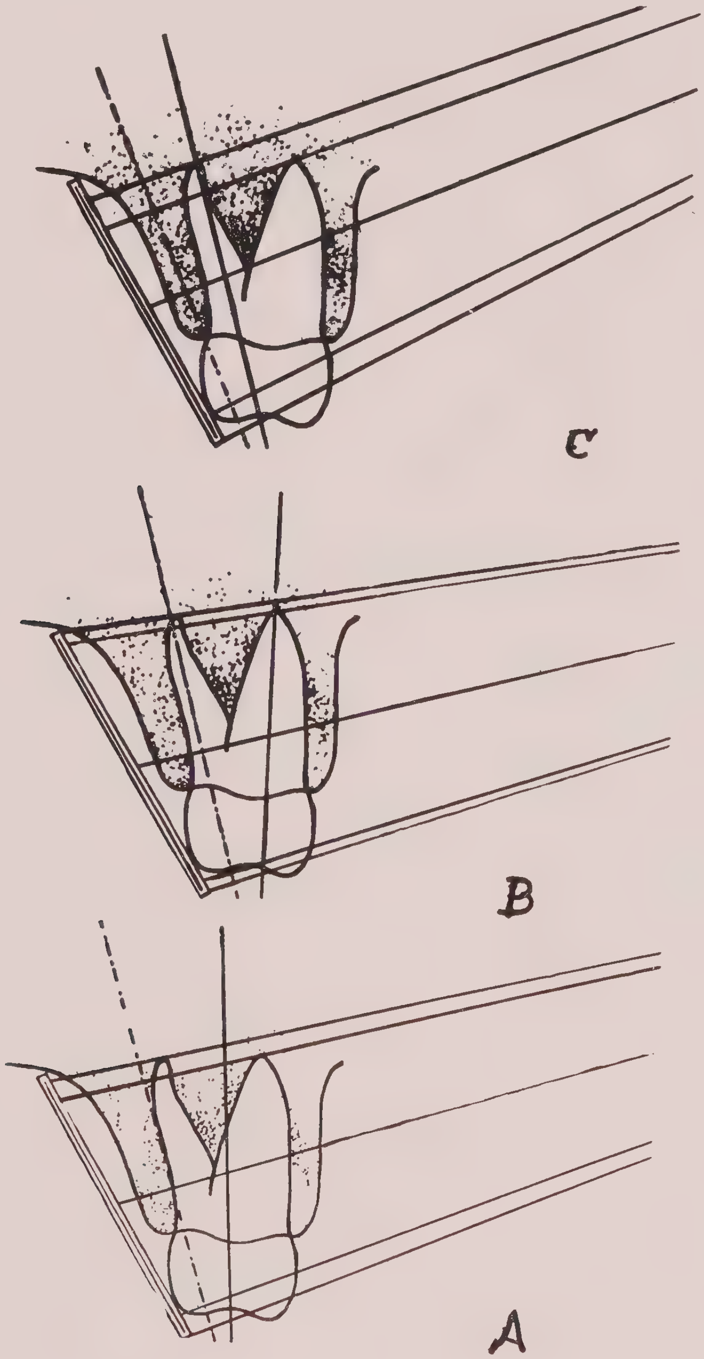


Fig. 39.—Technic for the upper molar teeth.

sired concerning an upper molar. The plan of procedure is shown in Fig. 39, *A*, *B*, and *C*.

If a general picture of the molar is desired (shown by

A), the plane of the tooth is assumed as lying midway between buccal roots and lingual root, and the rays are passed in perpendicularly to the plane lying midway between this assumed plane and the film. In the resulting radiogram none of the roots will appear in their exact proportions, but the buccal roots will be slightly shortened, while the lingual root will be *slightly lengthened.*

When it is desirable to obtain a radiogram of the buccal roots in their *exact length,* they must be assumed as being the plane of the tooth (*B*) and the rays must pass in perpendicularly to a plane lying midway between them

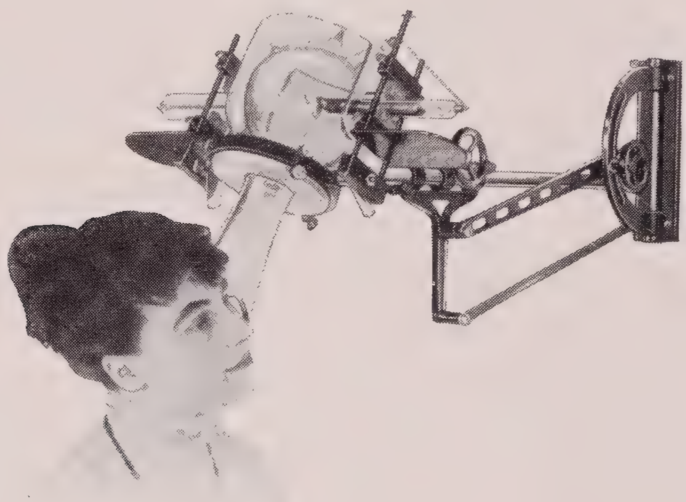


Fig. 40.—Special compression cylinder made of leaded glass.

and the film. In this event, the image of the lingual root is elongated.

If the lingual roots are under scrutiny (*C*), they must be considered the plane of the teeth, and the rays passed in perpendicularly to a plane lying midway between the lingual root and the film. In this event, the image of *the lingual root will have its correct proportions,* but the image of the buccal roots will be slightly shortened.

The upper molars are by all means the most difficult teeth to radiograph; that is, to obtain radiograms that are as comprehensive as those made of the other teeth.

However, by going to the extra work entailed by the foregoing procedure, valuable radiographic information can oftentimes be gained.

The task of radiographing the upper molars and premolars can be rendered less difficult by using a special compression cylinder made of leaded glass, as shown in Fig. 40.* The end of the glass cone or cylinder is beveled at the end so that it can be placed close to the face and still remain at the desired angle, its glass construction

Fig. 41.—The patient can hold the film in position against the lower teeth by exerting slight pressure with the finger.

enabling the operator to view the area under exposure at all times, and thereby lessen the liability of inaccurate work.

With the lower teeth (Fig. 41) we do not have this difficulty to contend with to so great a degree, as the films can be placed for the most part in such a position that they lie parallel to the long axis of the teeth, and the rays can be directed in a perpendicular direction both to the plane of the teeth and the plane of the film.

In placing the films in the mouth preparatory to mak-

*Suggested by Dr. F. K. Ream.

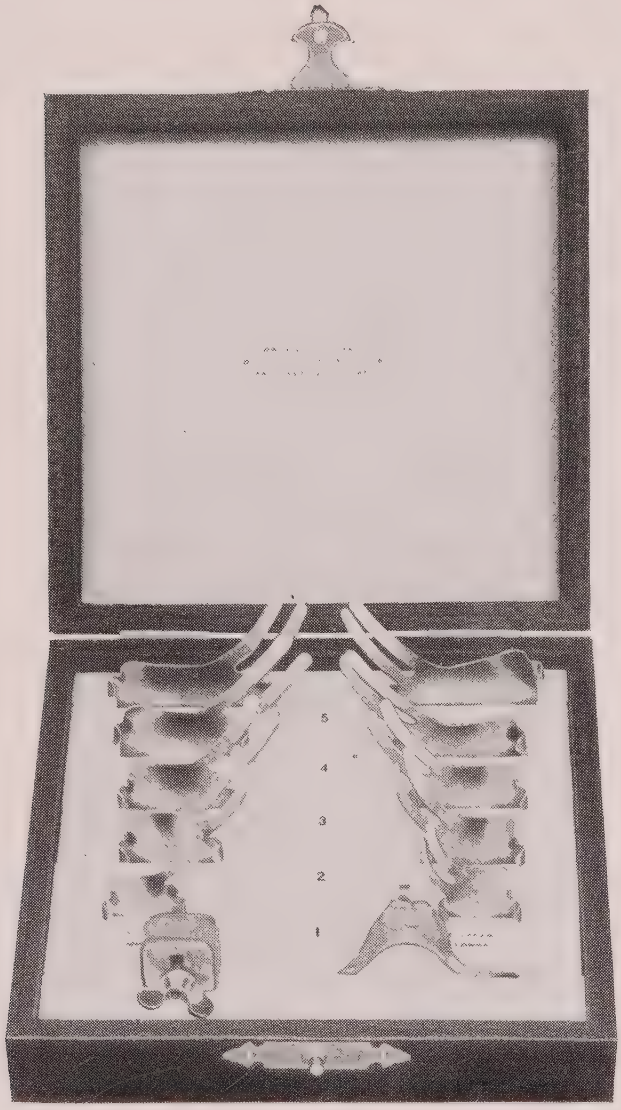
ing radiograms of the lower teeth, difficulty is sometimes encountered, owing to the fact that the tissues are usually quite sensitive. Inasmuch as the film must be *pressed well down between the tongue and the teeth,* it is advisable to first see that no sharp corners exist on the film covering, or better still, provide a rubber envelope or film holder *which has no sharp corners.* Such an envelope is easily improvised by the use of ordinary black vulcanite rubber. A pieceof this rubber which should be a little more than double the size of the film, is wrapped about it and the free edges pressed together. These edges are then trimmed with a pair of scissors so that the corners are rounded. Such an envelope containing the film can be introduced into the mouth and placed well down on the lingual side of the teeth with a minimum amount of discomfort to the patient.

Film Holders.—Some operators prefer to use a film holder to support the film during exposure. Of these, there are several varieties upon the market, all of which will accomplish the work for which they are intended.

THE KETCHAM FILM HOLDER.*—The Ketcham film holder consists of a metal block with a rubber band around it, which can be quickly changed, a bolt secured by a wing nut to pass through a slot in the block, and five pairs of film holders. These film holders are rights and lefts, and graded in size, and shape, so as to fit different mouths. (See Figs. 42-*A, B,* and *C.*) A "stereoscopic finder" is also a part of this set, which allows the operator to make a second radiogram of a given area, by removing the exposed film and placing another in its place in exactly the same position.

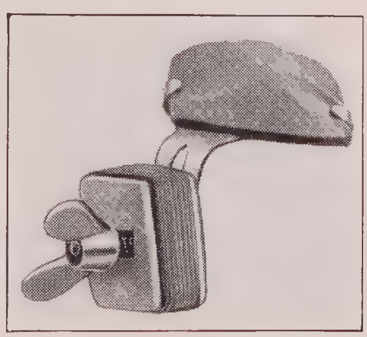
THE LEACH FILM HOLDER.†—The Leach film holder is very simple in design, and two film holders constitute a set. (See Fig. 43.)

*Designed by Dr. A. H. Ketcham.
†Designed by Dr. F. D. Leach.



A.

B.



C.

Fig. 42.—The Ketcham film holder. *A,* right and left film holders in graded sizes; *B,* metal block with film holder attached to it and film in position ready to be placed in the mouth. By closing the teeth upon the metal block, the film holder is held in the position desired; *C,* stereoscopic finder attached to the film holder.

With these, the patient holds the film in position by grasping the handle part of the holder, and the operator can by noting the angle of the handle, determine the direction in which the rays must be directed.

The smaller holder is designed for the upper six and lower eight anterior teeth, and the larger holder is designed for the posterior areas of the mouth.

THE DORR FILM HOLDER.*—The Dorr film holder is designed so that the film is held in position for exposure

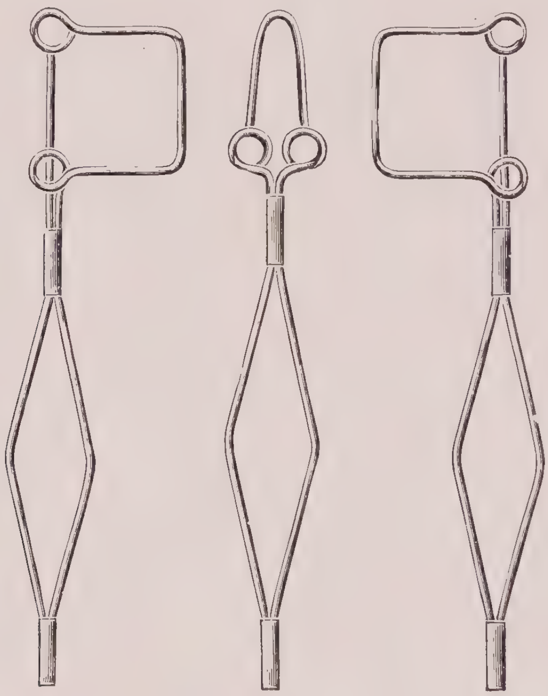


Fig. 43.—The Leach film holder.

by closing the teeth upon a flange which is part of the holder. (See Fig. 44.) A removable handle is attached to the edge of the flange and assists in placing the film holder (carrying the film) in the desired position in the mouth, after which the handle can be removed.

Two film holders constitute a set of which one has an obtuse angle and is designed for the upper teeth, while the other is placed at right angles to the flange and is intended for use upon the lower teeth.

*Designed by Dr. P. P. Dorr.

Where it is necessary to make a complete radiographic examination of the dental arches, it can be accomplished in the average case, by making six exposures of each arch. The procedure to be followed is diagrammatically shown in Fig. 45. The numbers *1, 2, 3, 4, 5, 6* indicate the position of the x-ray tube in its relation to the dental

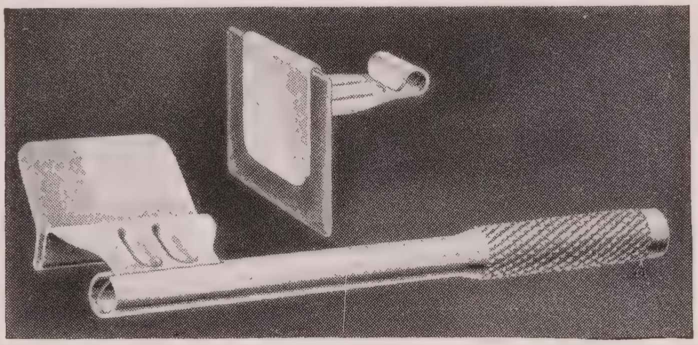


Fig. 44.—The Dorr film holder with detachable handle.

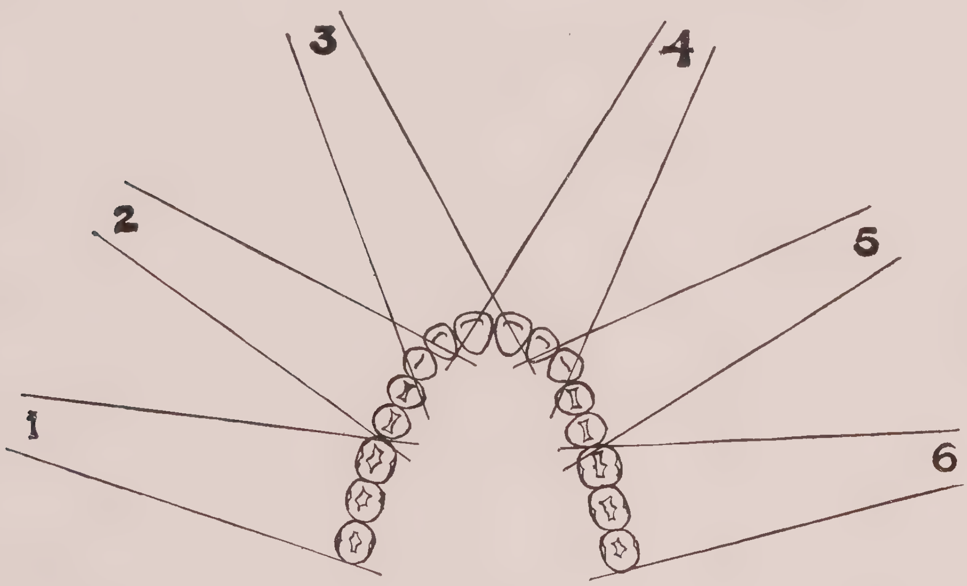


Fig. 45.

arch, and the ends of the lines coming from the numbers show the position of the mesial and distal edges of the film used for each exposure. It will be noted that each adjacent film position overlaps its neighbor which is advisable so that no area is left out.

In making radiograms of the anterior part of the arch, it is a mistake to attempt to radiograph more than two

or three teeth at a time, as the curvature of the arch usually renders it impossible to get more than that number free from distortion.

Another point in technic which should not be overlooked if sharp outlines are to be obtained, is the one in regard to having the tube placed at the proper distance from the structures to be radiogaphed. To establish the best focal distance for work about the teeth or jaws, the target of the tube should be about twenty inches from the plate or film.

With a good x-ray machine, and a properly regulated tube, good radiograms can be obtained by very short exposures, particularly by using the intra-oral method, as the rays need only penetrate a comparatively short distance before reaching the film. With the apparatus now available good radiograms can often be obtained by instantaneous exposures. However, instantaneous exposures are not necessary for good dental radiography. X-ray apparatus which is capable of producing sharp, clear "intra-oral" radiograms in from two to five seconds, is efficient enough for use in the x-ray laboratory of the dentist.

Extra-oral Method

The extra-oral method is, in the author's opinion, the one offering the widest range of usefulness in our work. As stated previously, this is the method used to obtain radiograms of large areas. Not only can larger areas be obtained by this method, but locations and structures inaccessible to the small films are reached and their images accurately and clearly recorded upon the larger plates. Therefore, the advantage of this method is well founded.

The technic is simple when once mastered, but must be adhered to accurately if the results are to be depended upon for diagnosis. In using the extra-oral method, large

plates or films are used and the areas desired are brought in as close contact as possible with the plate, *by pressing or resting the side or portion of the face upon which the structures desired are located, against the plate.*

First of all, the patient must be placed in a position so that *the head can be held perfectly still.* The dental chair with a few adjustments offers an excellent means for accomplishing this. One of the chair arms is lowered down against the side of the chair or removed, and the

Fig. 46.—The headrest of the dental chair with its many adjustments can easily be arranged so that the patient's head may rest easily and firmly upon it.

patient placed sideways in the chair. The chair back is adjusted so that the patient lies against it in an easy position, and the headrest wings are adjusted so as to lie flat and thereby form an excellent resting place for the plate. The headrest with its many possible adjustments can easily be placed so that the patient's head rests easily and firmly upon the plate, rendering it an easy matter to remain perfectly quiet. This position is shown in Fig. 46.

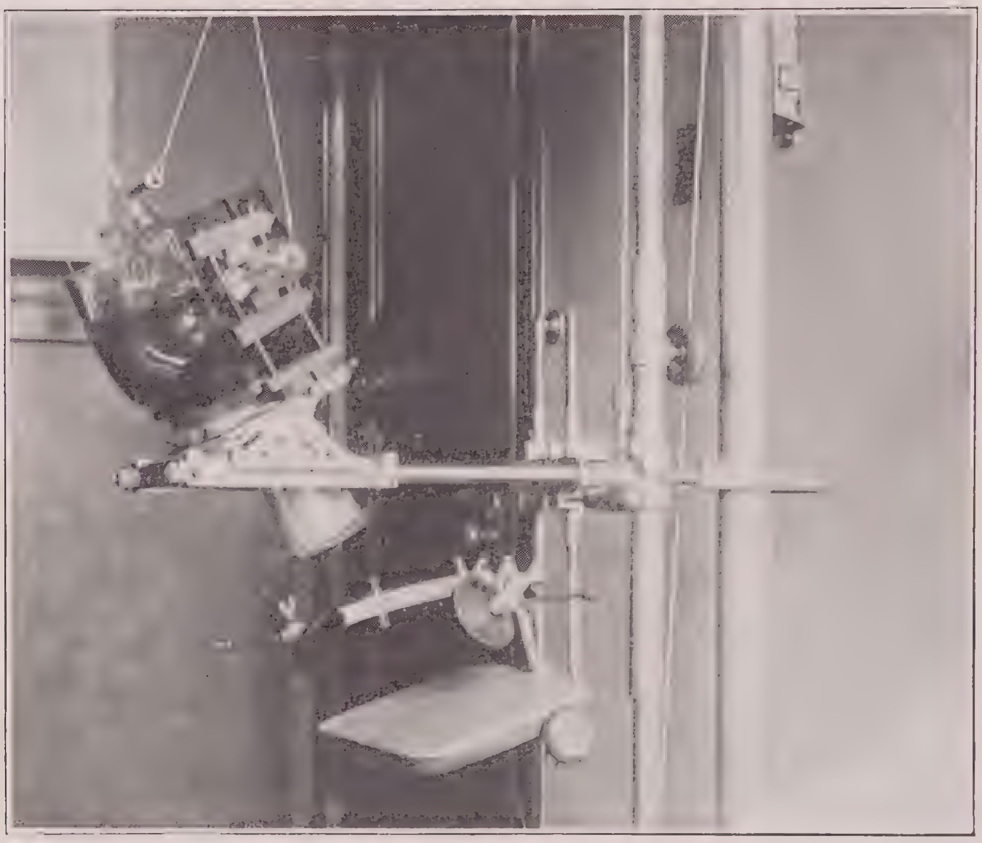


Fig. 47-*A*.—Tube stand with platerest and head support. (Eisen and Ivy.)

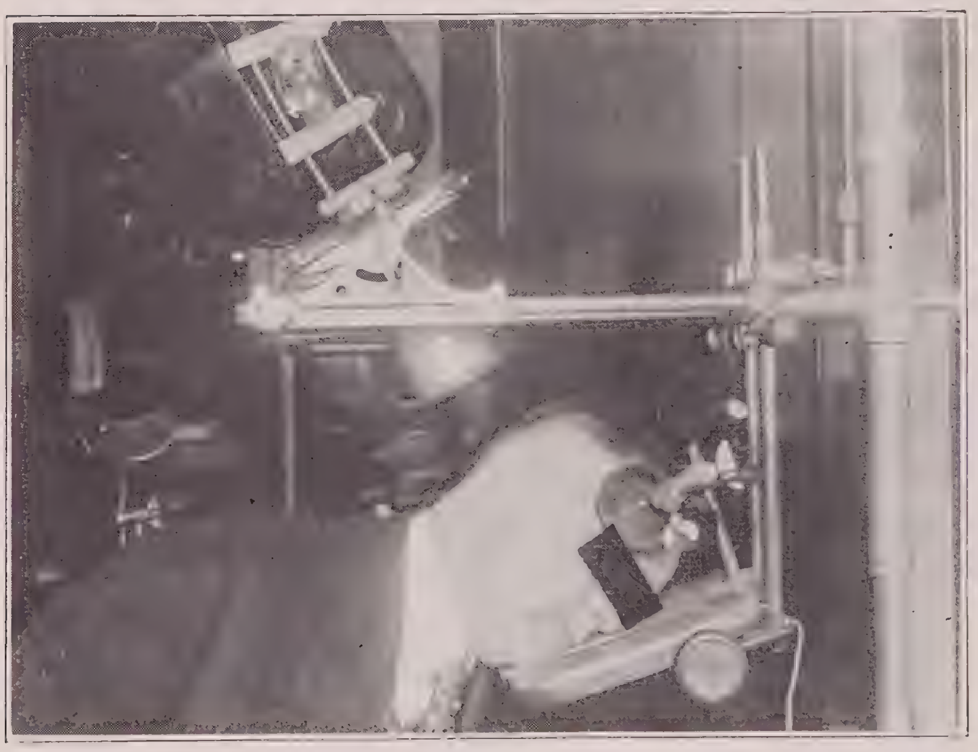


Fig. 47-*B*.—Position of head and angle for left side of jaws. (Eisen and Ivy.)

Fig. 48.—The arrangement of the apparatus preparatory to seating the patient.

Fig. 49.—The patient seated and the apparatus arranged for making a radiogram of the left side. The comfortable position of the patient renders it an easy matter to remain perfectly quiet.

For this character of work some operators prefer to use a platerest and head supporting device attached to the tube stand as shown in Fig. 47-*A*. Where such a method is followed, the head is supported in its proper relationship to the plate as shown in Fig. 47-*B*.*

Author's Method of Seating the Patient

In the author's opinion, there is another method of seating the patient for this character of work which will be found to be advantageous where such special apparatus is not available. It is accomplished by using an ordinary chair with a straight back and small arms, placed against the back of the dental chair. The headrest of the chair is turned over and adjusted to the proper height, position and angle, so that the patient's head can rest against it in any desired position. In this way the patient is afforded the firm support of the heavy dental chair, and, therefore, has little difficulty in remaining perfectly quiet, and the operator can by making a few changes in the position of the small chair, by moving and readjusting the tube stand and the headrest, have radiographic access to any part of the oral cavity or associated structures. The arrangement of the apparatus preparatory to seating the patient is shown in Fig. 48.

The fact that this requires but a few moments, does not disarrange the office, or put the patient to discomfort, justifies the author in feeling that it is by all means the preferable method for use in the average dental office.

With the head thus supported, as shown in Fig. 49, the rays are directed from the opposite side of the head, and, therefore, must pass through the entire face or skull in transit. The question naturally arises, how is this to be accomplished without superimposing the shad-

*Eisen, E. J., and Ivy, Robert H.: American Journal of Roentgenology, May, 1916.

ows of one side upon the shadows of the other side, and thereby producing a chaotic result.

For instance, let us suppose that we wish to obtain a radiogram of the left side of the upper and lower jaws extending from the cuspid region in front to the angle of the jaw behind, and from the floor of the orbit above to the inferior margin of the mandible below. If we are to get a correct shadowgraphic representation of this area, it should be free from the shadows of the opposite side, *and this can only be accomplished by directing the rays in such a manner that they will miss the areas not desired and will pass through those we wish to record.*

In accomplishing this, we must take into consideration two structures; viz., the spine and the ascending ramus of the mandible (on the right side in this instance as the left side is to be radiographed) and cause the rays to pass in through this opening and thereby reach the desired area. The way in which this is accomplished is shown in Fig. 50, *A* and *B*, and Fig. 51, *A* and *B*.

An important factor in accomplishing this is the position in which the patient's head is held as it is pressed against the plate. Held in the manner shown, the rays can be made to pass in between the ascending ramus of the mandible and the spine, and can pass in at approximately a perpendicular direction to the long axis of the teeth and the plate, giving correct shadow lengths upon the plate. Fig. 52 shows a radiogram made by using this technic.

If this rule is disregarded and the rays passed through the structures, as shown in Fig. 53, *A* and *B*, the shadows of the opposite side will be superimposed upon the shadows of the structures desired, and a chaotic result produced. The result of such technic is shown in Fig. 54.

In a similar manner as shown in Figs. 50 and 51, with slight adjustments in the position of the plate, the head,

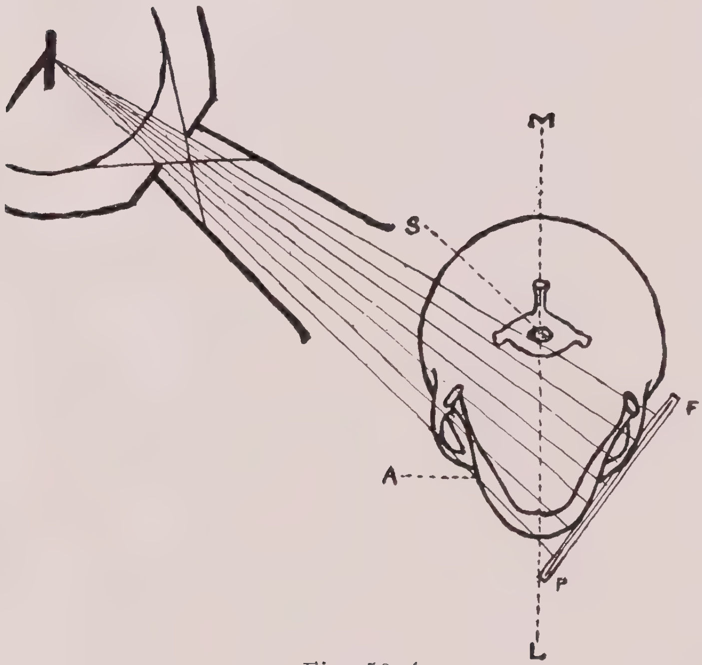


Fig. 50-*A*.

Fig. 50-*B*.

Fig. 50.—Technic for left side. *M-L,* median line; *S,* the spine; *A,* ascending ramus and angle of lower jaw; *P-F,* plate or film.

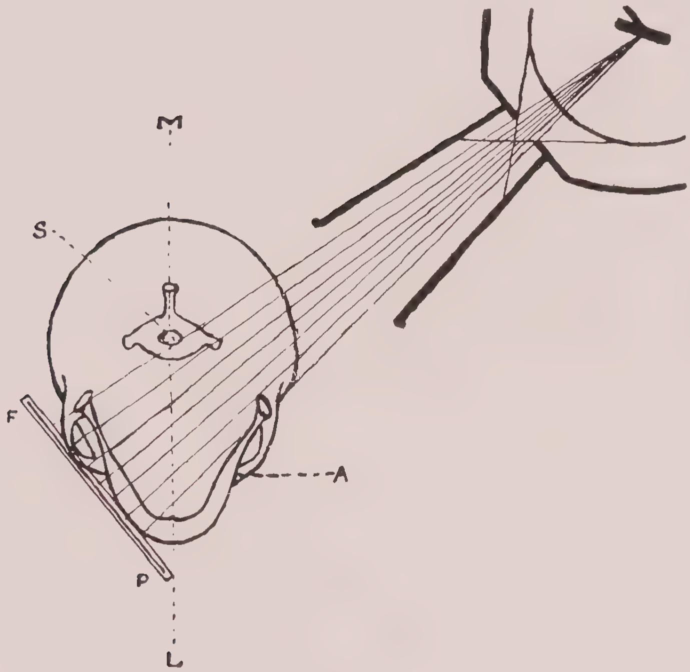


Fig. 51-*A*.

Fig. 51-*B*.

Fig. 51.—Technic for right side. *M-L*, median line; *S*, the spine; *A*, ascending ramus and angle of lower jaw; *P-F*, plate or film.

and the tube, the areas in the upper and lower jaws extending from the median line to the first premolars, and from the nose above to the inferior margin of the mandible below, can be radiographed (Fig. 55, *A* and *B*).

Fig. 52.

Likewise the structures at the median line including the incisors, both above and below, the anterior portions of the mandible and maxilla, the nasal cavity and its accessory sinuses, may be radiographed by passing the

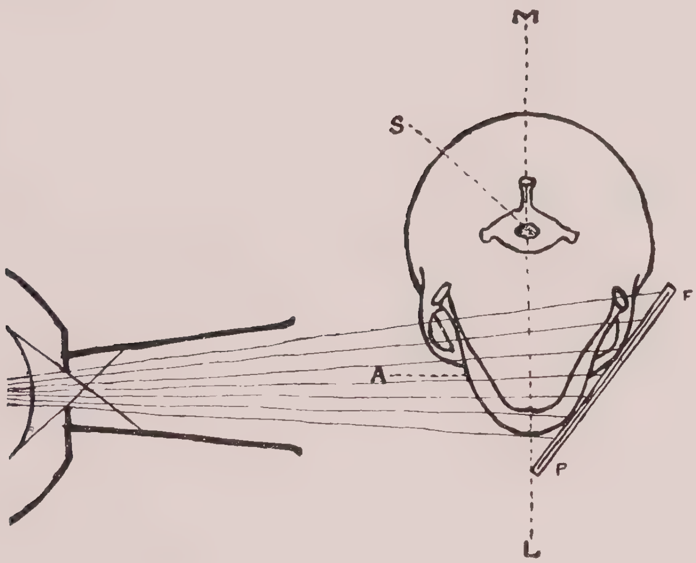


Fig. 53-*A*.

Fig. 53-*B*.

Fig. 53.—Incorrect technic. The shadows of both sides will be imposed upon the plate.

rays directly through the skull, as shown in Figs. 56 and 57. In this instance, the shadow of the spine will be superimposed upon the dental structures, but owing to

Fig. 54.—The result of incorrect technic. This is a radiogram of the same subject as shown in Fig. 52.

the fact that it is so far removed from the plate, its shadow does not interfere seriously. It is important, in making these pictures, to have the patient's head supported in such a manner that it can be held still for a

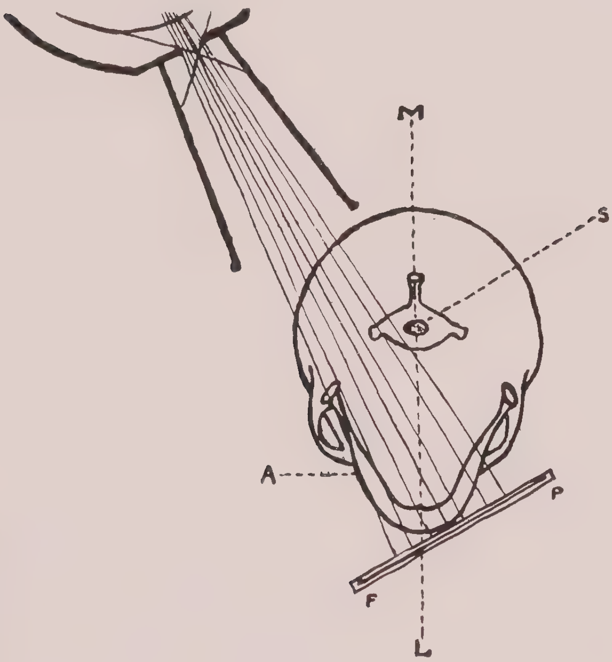


Fig. 55-*A*.

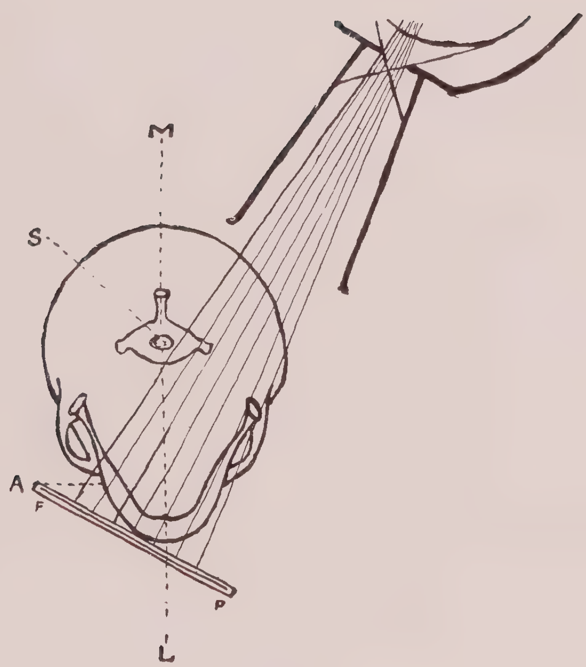


Fig. 55-*B*.

Fig. 55.—The areas in the upper and lower jaws extending from the median line to the first premolar can be radiographed by utilizing this technic. *A*, technic for left side; *B*, technic for right side.

longer period than is required in making the exposures of the other areas mentioned.

When ready to make the exposure for extra-oral radiograms, the apparatus is arranged with the anode of the tube about twenty inches from the plate. The patient is instructed to *keep the mouth closed with the teeth together in their natural occlusion.* They should also be warned as to the approximate length of time the exposure will require, and that *they must remain perfectly quiet.*

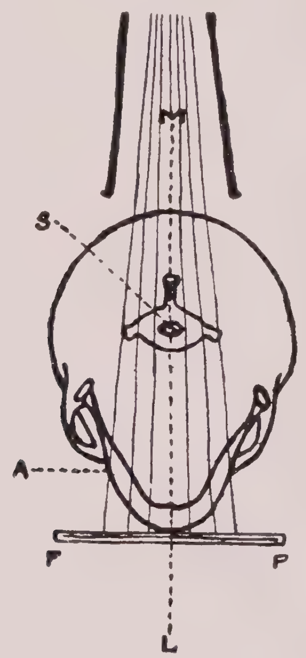


Fig. 56.—The structures at the median line including the incisors, both above and below, may be secured in this way.

With the more powerful types of apparatus, extra-oral radiograms require but short exposures, but if an operator does not possess high power apparatus, he should not hesitate to use this method, as a patient properly seated and supported, as shown in Fig. 49, can easily remain quiet for five or ten seconds, or perhaps even longer, should it be necessary.

In making a complete radiographic examination of the teeth, the maxilla and mandible, the author suggests the following procedure. Extra-oral radiograms should be

made of each side, using the technic illustrated in Figs. 50, 51, and 55. This would mean two plates for each side. Then by the use of intra-oral films, the region lying between the cuspids both above and below, should be radiographed. These plates and films should then be developed and examined. If the procedure has been carried out with due regard for all the elements involved, the result should constitute a general radiographic sur-

Fig. 57.—In following the technic illustrated in Fig. 56 the patient's head should be supported by a bandage of gauze to insure perfect immobility.

vey of the teeth, the maxilla and the mandible. Should any of the plates or films exposed fail to result in good radiograms, additional exposures should be made, as nothing but good radiograms should be depended upon for diagnosis.

It is sometimes advisable after making a complete radiographic examination by the method just advocated, "to check up" the findings of extra-oral radiograms by the use of the intra-oral films. For instance, suppose a large

plate shows what appears to be an abscess upon the root of an upper bicuspid or molar tooth. An intra-oral radiogram of this particular area will often settle any doubts, as a higher degree of detail can often be obtained by concentrating upon the small area in question.

The author would not wish to imply by the preceding remarks upon technic, that the few rules enumerated constitute a safe and never failing means of producing good radiograms. There are many points to be considered which can not be included in so limited a text, but which must be learned in the school of experience, such as the necessary variations from the given rules of technic because of anatomic variations in the dental and oral structures of patients. Therefore, the rules of technic which have been presented must be accepted only in the light of principles.

CHAPTER VII

TECHNIC OF DENTAL AND ORAL RADIOGRAPHY

(Continued)

Successful radiography depends upon a sequence of operations, each of which must be carried out with scientific accuracy. These steps, upon which the finished product depends, may be enumerated as follows:

1st—Correct technic of position.

2nd—Proper tube and current conditions.

3rd—Correct exposure and development of plates and films.

It would be difficult to determine which of these steps is the most important; in fact, they are all so important that a radiogram is a success or failure in accordance with the degree of accuracy with which each is carried out. In the preceding chapter, the actual technic of radiography, so far as the arrangement of apparatus is concerned and its relative position to the patient and the plate (or film), has been discussed. We will, therefore, proceed to the next factor for consideration.

Proper Tube and Current Conditions

The character of the x-rays produced in a tube depends upon the degree of its vacuum and the current which passes through it. We know that the x-rays are produced by the cathode stream striking the anode or target, and that this cathode stream (Fig. 59-*M*) is generated by the flow of the current in the tube. *The velocity of the cathode stream depends upon the voltage of the current entering the tube,* therefore, the higher the

voltage, the faster the cathode stream travels, and *the more intense or penetrating are the x-rays produced. The quantity of x-rays produced depends upon the milliamperage of the current.*

In considering the role enacted by the voltage and milliamperage in the x-ray production, we have assumed that the tube is exhausted to a high degree of vacuum, for the degree of vacuum determines to a large extent, the value of the other two factors. The degree of vacuum of a tube is designated as high, medium, or low, a ''high tube'' being one in which the vacuum is well nigh complete; in a ''medium tube'' the vacuum is less complete, while a ''low tube'' is one in which the vacuum is far from complete.

For dental radiography *a fairly high tube* is indicated, as with such a tube x-rays may be produced having a degree of penetration sufficient to pass thsough the oral structures and produce the desired effect upon the emulsion of the plate or film.

When a current of high voltage is passed through such a tube, it should light up in a characteristic manner forming two hemispheres which have a definite line of demarcation. The hemisphere in front of the target which is the active hemisphere, is evident by a fluorescence deep apple green in color, while the other hemisphere should be evident by a lack of greenish light.

To Determine the Vacuum of a Tube

The comparative degree of vacuum of a tube can be determined in the following manner: Connect the tube to the x-ray machine as shown in Fig. 58. See that the third terminal (*S′*) is moved well away from the negative terminal (*S*), or better still, disconnect the wire running to the regulation chamber (*R*). Now, move the sliding rods (*B* and *D*) of the secondary spark gap, to-

ward each other until they are about three inches apart, and start the current. Unless the tube is *low,* the current will jump the spark gap instead of passing through the tube. If the tube resists the current and causes it to jump the spark gap, it is said to have "backed up" three inches of spark. Thus a "low tube" will back up

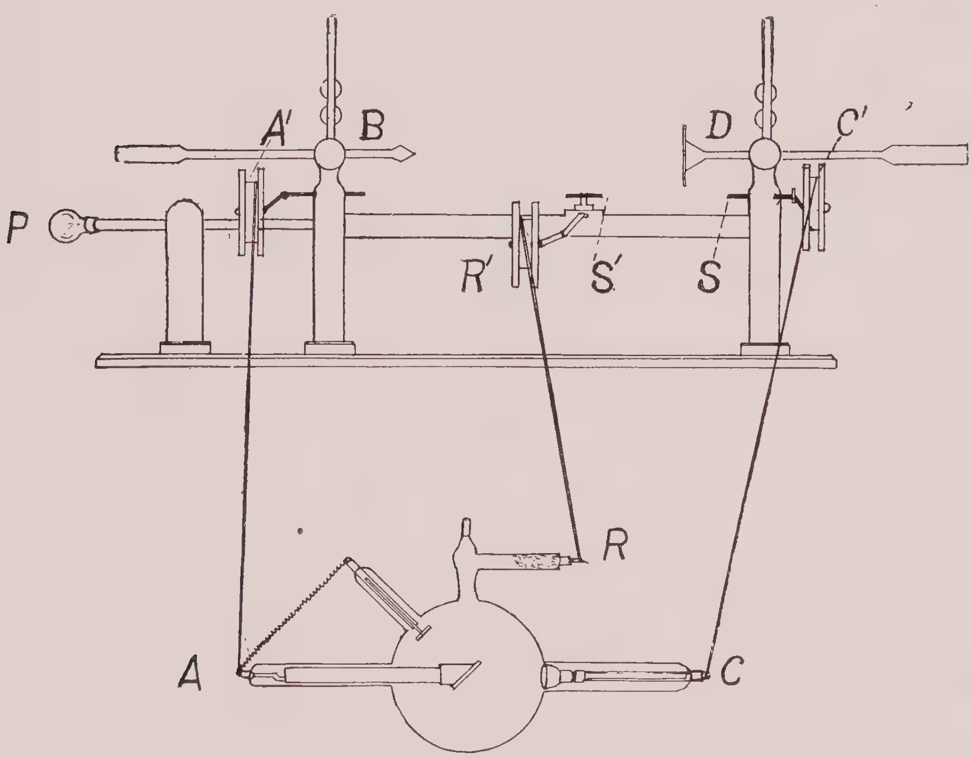


Fig. 58.

two or three inches of spark, a "medium tube" five or six inches, while a high tube will back up six or eight inches. In fact, the vacuum of a tube may be so great that only the most powerful x-ray machines will operate it. Such a tube, however, is not useful for dental radiography.

The vacuum of a tube may also be determined by the use of an instrument known as a *milliamperemeter.* This instrument which is usually an accessory of either the induction coil or transformer, is connected in circuit with the tube, and measures the current passing through the tube. With a "low tube" the milliamperemeter will

show a reading of 15 to 18, while with a "medium tube" the reading will be from 10 to 12, and with a "high tube" the milliamperemeter will register 5 or less.

Relative Merits of Low, Medium, and High Tubes

A low tube under average current conditions gives a clear sharp hemisphere of pale greenish light in front of the target, with usually a trace of bluish light in the region of the assistant anode. If the tube is very low, the cathode stream shows blue, and there is a bluish light back of the active hemisphere. Such a tube will not do good radiographic work, as the x-rays produced by it are lacking in penetration.

A "medium tube" gives a clear, sharp hemisphere of light greenish color, and there is an absence of bluish light back of the target. The rays emanating from such a tube are more penetrating than those from the "low tube," but are not so well suited for "bone radiography" as those which come from a tube fairly high in vacuum. When such a tube is operating, it gives a clear sharp hemisphere deep apple green in color, with a lack of greenish light back of the target. The x-rays emanating from such a tube *are of degree of penetration which is best suited for bone radiography,* for they penetrate and pass through the soft tissues and to a sufficient degree through the bone structure to give good contrast.

It is very important that the vacuum of such a tube be kept uniform, for if it gets low, the power of penetration of the rays is decreased, and, on the other hand, if the vacuum gets too high, the penetrating power of the rays will be increased, with the result that they will penetrate through the bone structure as easily as the soft tissues. Consequently, unless very short exposures are given, there will be little if any contrast and the plate will be dark and hazy.

Regulating the Tube

Prior to seating and arranging the patient, the tube should be tested out and any needed change in its vacuum effected. This is easily accomplished by utilizing the third terminal of the x-ray machine. The tube should be connected to the machine as shown in Fig. 58. The terminals of the regulating spark gap ($S'S$) should be placed about four inches apart, and the current (of correct working strength) turned on for an instant. If a line of sparks jump between S' and S, it shows the vacuum of the tube is too high. In this event the regulating spark gap ($S'S$) should be reduced to about two inches, and a *small amount of current turned on.* This weaker current will pass across the spark gap ($S'S$), travel down the wire connected to the regulating chamber, and by heating the asbestos (impregnated with chemicals), will liberate enough gas to reduce the vacuum. Unless the tube is very high, a few seconds will suffice to reduce it to the vacuum desired. To be sure the vacuum is right, the regulating spark gap ($S'S$) should be widened to about four inches, and the desired working current again passed through the tube for an instant. If the tube lights up with a clear sharp active hemisphere deep apple green in color with a lack of greenish light back of the target, you then know it is ready for work.

If an x-ray machine is not equipped with a third terminal, the same results in regulating the tube may be effected by using the regulating adjuster (Fig. 59), the end of which can be placed at the desired distances from negative wire near its point of attachment to the tube. The tube may also be lowered by attaching the negative wire directly to the regulating chamber and passing *a small amount* of current through the circuit.

These manipulations should be carried out *with the*

greatest caution, for a tube is an extremely delicate and sensitive piece of apparatus and will not stand abuse.

A careless operator can quite easily reduce the vacuum to such a degree that the tube is useless. Such a tube has a purple appearance when the current is passed through it. If such a tube has not been too greatly abused, it will often regain its vacuum if given a rest. If this does not bring the vacuum up, it can often be brought back in the following way: The spiral spring (Fig. 59) connecting the anode and assistant anode should be removed and the positive wire from the machine attached

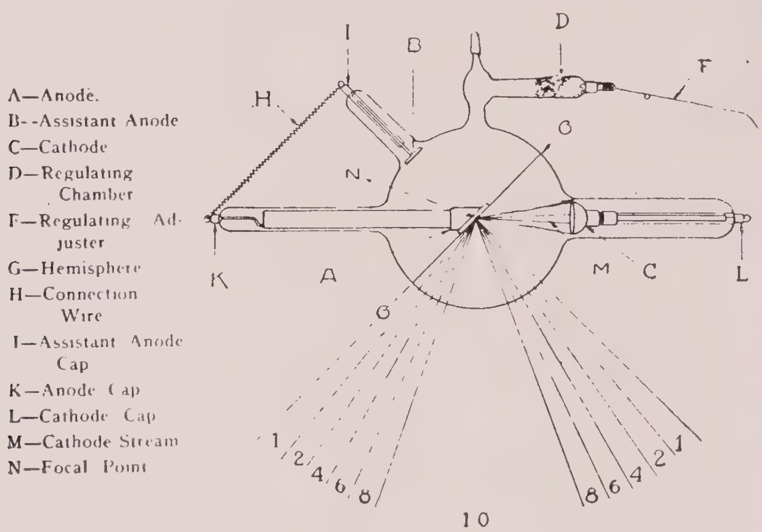


Fig. 59.

to the assistant anode (I). The negative wire is attached as usual (at L) and *a light current is run through the tube* for a minute or two at a time. If this is done once or twice a day for several days, the vacuum will usually come up. Any increase in vacuum will be indicated by the milliampere readings dropping off, or by the increased length of spark gap the tube will "back up."

If a tube does not respond to this treatment but continues to be purple while operating, it indicates that it is practically nonvacuous or "punctured." It is then useless and should be sent back to the manufacturer for

repairs. In the event a tube is "completely punctured," the current in passing through it simply jumps the gap between the anode and cathode, and is evident as a line of white sparks.

One tube complication not yet mentioned is sometimes encountered in the use of induction coils. This is known as "inverse in the tube," and is the result of the presence of inverse current (current in the wrong direction) in the secondary circuit of the coil. "Inverse" is evident in the tube by the appearance of rings of light back of, and usually running at an angle to, the active hemisphere, or by a fullness of greenish light back of the active hemisphere, with rings about the assistant anode.

Inverse current in a tube will generate secondary rays which have the tendency to make the outline of the image on the plate hazy or "less sharp," as these rays are produced in the tube elsewhere than at a focal point on the target. It also produces heat in the tube which lowers the vacuum and hence lessens the penetration of the rays coming from it.

"Inverse" in the tube can usually be controlled or prevented by the use of "a multiple spark gap" or "a valve tube" arranged in series with the x-ray tube, and by using a tube which *is fairly high in vacuum.* If it still persists after these precautions are taken, it indicates an imperfect adjustment of the induction coil or some of its accessories.

All manufacturers of x-ray tubes furnish full instructions as to the care of and manner of using x-ray tubes. These instructions should be carefully read and *explicitly followed.*

In order that uniform results may be obtained, it is advisable to always use the tube at the same vacuum, with the same amount of current. The proper "working current" may be determined in the following way:

With the tube disconnected, set the sliding rods (*B* and *D* of Fig. 58) of the machine about six inches apart. Then start the current in the machine, and beginning with a low current increase it until a fat fuzzy "caterpillar spark" is produced across the spark gap. As soon as this spark or discharge appears, the switch should be pulled out, but the rheostat or other controlling apparatus left as it was when the spark appeared, so that when the tube is connected, the proper working current will come from the machine.

The tube should then be connected up and given a trial. If it is not too high in vacuum, it should take the current, or in the event it is too high, it will "back up" the spark, and the discharge instead of passing through the tube will jump the gap. If the tube requires regulating, it can be done by the methods before described.

With the working current and vacuum established, it is a good idea to separate the sliding rods on the machine to at least eight inches, to insure against the tube backing up the current, for in the event the tube should start going up during the time the exposure is being made, the startling noise made by the discharge jumping the gap, may cause the patient to move and thereby blur the radiogram. If several exposures of five or ten seconds each are made, the tube should be given sufficient rest between exposures so that it will not heat up. This is important.

With proper tube and current conditions, the length of time required for the exposure will depend upon the type of x-ray machine used, and the thickness and density of the parts to be radiographed, varying with different patients according to age and structural make up.

CHAPTER VIII

CORRECT EXPOSURE AND DEVELOPMENT OF X-RAY PLATES AND FILMS

X-ray plates and films differ from those used in ordinary photography in that their emulsion is more sensitive and better adapted to record the shadows produced by the x-ray. Therefore, they should always be used in preference to ordinary plates and films.

The same general photographic rules apply to x-ray plates and films as apply to the ordinary kind, except perhaps that they demand a greater degree of accuracy and care throughout the process of exposure and development, if the very best results are to be obtained.

X-ray Plates

X-ray plates are supplied by the manufacturers, packed in lightproof boxes containing one dozen plates. They are obtainable in any desired size, but for dental and oral radiography, a 5x7 plate is large enough. If stored in the laboratory, they should be kept in a lead-lined box prior to their preparation for exposure, or they will become "fogged," as lightproof boxes offer no protection whatever from the x-ray.

A suitable plate and film storage box is shown in Fig. 60. Such a box should be about twelve inches square and five inches deep. This will enable the storage of several boxes of 5x7 plates, and in addition, three or four dozen dental films.

In their preparation for exposure, each plate is placed in two lightproof envelopes, one of which is black and

the other red or orange in color. Such envelopes are furnished by plate manufacturers and are obtainable in the desired size. *The transference of the plate from its original box to the envelopes must, of course, only be done in the photographic darkroom.* The plate is first slipped into the smaller envelope which is usually the black one, with the emulsion side of the plate facing the smooth side of the envelope (the side free from seams or overlapping edges). The envelope containing the plate is then placed in the larger or yellow envelope, flap-end first, with the smooth side of the inner envelope facing the smooth side of the outer one. Plates prepared in

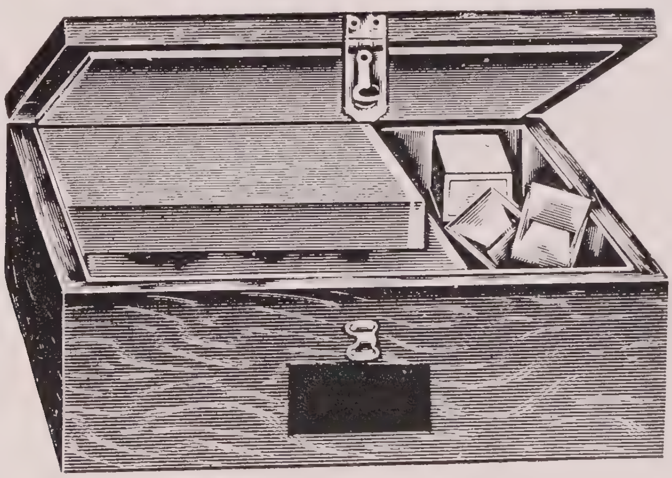


Fig. 60.—X-rayproof film and plate chest.

this way are then ready for exposure and can be placed back in the lead-lined box until needed.

In "loading these envelopes," care should be taken lest the emulsion of the plate become scratched, as scratches even though they be very slight will often curtail the value of the finished radiogram.

It is not advisable to keep large quantities of plates loaded in envelopes, unless they are to be used within a few days, as the contact of the paper with the emulsion will in time affect it adversely.

All "brands" of x-ray plates are not the same, therefore, if the best results are obtained in using any par-

ticular kind, they must be handled in strict accordance with the manufacturers' instructions. For dental and oral radiography, a plate should be fairly rapid (that is, it should not require a long exposure), give a high degree of detail and good contrast, and should be uniform in its reaction to the x-ray.

X-ray Films

In making intra-oral radiograms, a film is preferable to a plate as it is flexible and, therefore, can be more easily adapted to the inside of the mouth. These films are obtainable in several convenient sizes, wrapped in lightproof and dampproof coverings ready for exposure. Like plates they should be kept in a lead-lined box for protection.

With these "dental films" as they are called, you have the choice of two different emulsions, one of which is much more "rapid" than the other.

The "rapid" or "fast film" requires only about one-fourth or one-third as long an exposure as the "regular" or "slow film," and therefore is an advantage to the radiographer who uses one of the less powerful types of x-ray machines. However, such a film does not have as much latitude as the slow film, and is therefore more apt to be overexposed. If properly exposed, either one will give satisfactory results.

When arranging a plate or film for exposure, *the emulsion side should lie next to the structures being radiographed.* If this rule is systematically followed, it is an easy matter to identify radiograms, i. e., whether they represent structures on the right or left side of the median line.

Development of Plates and Films

The process of "development" of either plates or films may be briefly described as follows: At a con-

venient time following the "exposure," the plate or plates (or films) are taken into the "darkroom." Such a room has all white light excluded from it, and is illuminated only by a so-called "ruby light" or darkroom lantern. The darkroom should be supplied with a shelf or table about two and a half feet wide and three feet long placed at ordinary table height from the floor, so that the operator may sit upon a stool while at work. Upon this shelf there should be four trays, one for the "developing solution," one for the "fixing bath," and the other two for water. Where a darkroom is supplied with running water and a sink, only three trays are necessary.

With all light excluded from the room except the ruby light coming from the darkroom lantern, the plate (or film) is taken out of its envelope and immersed *emulsion side up* in the devoloping solution. In order to insure a uniform action by the developer, the tray should be frequently rocked with a gentle motion. If the plate (or film) has been properly exposed, development should be complete in about five minutes (although the time varies with different formulæ).

The plate or film is then removed from the developer and placed in a tray of water to thoroughly wash the developing solution from it. This, of course, requires but a moment, and it is then immersed in the "fixing bath," keeping the emulsion side up. As soon as the plate has been in the fixing bath a few seconds, the darkroom door may be opened and light admitted without injurious effects. However, the plate (or film) must still remain in the fixing bath until it has "cleared" (until all milkiness is gone from the back of the plate), which will usually require from five to ten minutes. In fact, it is better to let it "fix" for at least five minutes longer than is required for it to become clear.

When the fixing process is complete, the plate must be placed in water and thoroughly washed to remove all the fixing solution from it. This can be accomplished by washing it in several changes of water, or better still, place it in a basin or tray of cold "running water" for ten or fifteen minutes.

When the washing process is complete, the emulsion side of the plate or film should be gently rubbed with a clean piece of wet cotton, holding the plate (or film) under a cold water faucet during the act. The developed radiogram is then ready to dry. Plates should be stood on edge or placed in a suitable rack so that nothing will come in contact with the emulsion side, and left until perfectly dry. Films may be pinned to the edge of a shelf, or secured to a line with suitable clips. The drying process should take place in a room free from dust or soot, for these will prove injurious to the drying emulsion.

The size of the trays used in the darkroom will depend upon the number of plates or films which are to be carried through the developing process at a time. For plates, the author uses trays 8x10 inches in size. With such trays two 5x7 plates can be carried through at a time. Where a large number of plates are being developed, additional trays can be used and if necessary "tanks" capable of holding a dozen plates, utilized in the fixing or washing process. In developing "dental films," small trays will be found convenient, and unless a large number are to be developed at a time, a 4x5 or 5x7 tray will be large enough.

Trays should be labeled according to the purpose for which they are to be used, *and used for that purpose only.* That is, developing trays should be used for the developer only, and fixing trays, only for the fixing bath, if troublesome chemical reactions are to be avoided.

Any one of several good formulæ may be used in the

developing and fixing process. The following has given satisfactory results in the hands of the author, and is easily prepared:

Developer

Water (distilled)	20 oz.
Metol	20 gr.
Hydroquinone	80 gr.
Sodium sulphite (dry)	1 oz.
Sodium carbonate (dry)	1 oz.
Potassium bromide	10 gr.

Fixing Bath

Solution A:		
	Water (distilled)	30 oz.
	Hyposulphite of soda	1 lb.
Solution B:		
	Water (distilled)	15 oz.
	Chrome alum	1 oz.
	Sodium sulphite (dry)	2 oz.
Solution C:		
	Water (distilled)	5 oz.
	Sulphuric acid (C.P.)	1/8 oz.

Add C to B (when cold) and the mixed solutions to A.

If the best results are to be obtained in developing, the temperature of the solution should be kept between 65° and 75° F. If the temperature gets much over 75°, the plate will develop too fast, while if the temperature goes much below 65°, development will be retarded.

It is a mistake to try to develop a large number of plates with the same mixture of developer, for after it has developed a half dozen plates, it will become weak and not give the best results. Therefore, do not hesitate to use *plenty of fresh developer* if you expect to get satisfactory results.

The same rule applies to the fixing solution. It must be *fresh and clean* to give good results.

Under proper tube and current conditions, and with correct length of exposure, a plate should require about five minutes for its development. An overexposed plate will not require so long, while an underexposed plate will require a longer time.

To get the most out of a plate, it should be developed until fairly dense, that is, until it is about the same color on each side. If, after it has cleared in the fixing bath, it appears *too dark or dense,* you know that it has been *overexposed.* Therefore, in making subsequent exposures *decrease the length of exposure.* If, upon clearing, the image on the plate is faint and indistinct, you have reason to think it has been *underexposed.* Therefore, *increase the length of exposure.*

By keeping the tube and current conditions right, the approximate length of exposure for any given case is easily determined by the operator, after a little experience. As stated before, this will depend upon the type of x-ray machine used, the thickness and density of the parts to be radiographed, and the age and structural make up of the patient.

CHAPTER IX

THE INTERPRETATION OF DENTAL AND ORAL RADIOGRAMS

The ability to correctly interpret dental and oral radiograms is an accomplishment which every dentist should possess. In fact, it should be viewed, not only in the light of an accomplishment, but as a requisite of modern dentistry.

Unfortunately, the assertion is not infrequently made by certain ill-informed members of the dental profession that only minor importance should be attached to the findings of the radiogram, their claim being that such images can be construed as showing conditions which do not actually exist.

Such an attitude can be explained as being the outgrowth of several things, among which a lack of knowledge of the fundamental principles of radiography and its various branches, and especially of the science of interpretation, stands as an important factor. Therefore, opinions of the x-ray and its application in dentistry expressed by those unqualified, should not be regarded seriously.

The idea also seems to prevail in the dental profession that the interpretation of radiograms is an extremely simple matter, requiring little if any preparation on the part of the one who is to make the interpretation. This erroneous idea is doubtless responsible, not only for many errors being committed, but also for a lack of greater appreciation by the profession of the value of the radiogram.

The first requisite of interpretation is an accurate knowledge of the anatomy and physiology of the structures involved, for a radiogram is a shadow picture, and a shadow picture is meaningless unless one is thoroughly familiar with the main characteristics of the original.

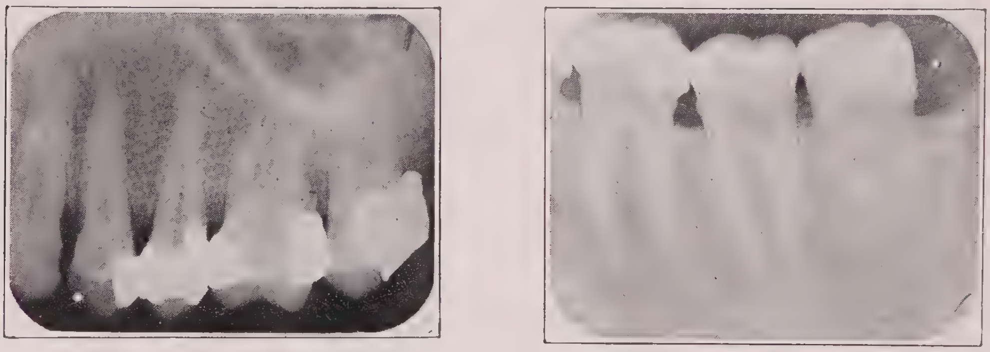
The radiogram may be said to vary from an ordinary shadow picture, as, in addition to mere outlines, varying densities are shown due to the fact that the x-ray penetrates all matter in inverse ratio to its mass or density.

If one is possessed of an accurate knowledge of the anatomy and physiology of the dental and oral structures, the next step toward acquiring the ability to correctly interpret radiograms of these structures, would be *to become familiar with their radiographic appearance under normal conditions,* for unless one be familiar with the appearance in the radiogram of the structures under normal conditions, it is obviously impossible to intelligently recognize pathologic or anomalous conditions unless they were of a glaring nature.

When we speak of the radiographic appearance of the structures under normal conditions, we refer, not only to a freedom from pathologic or anomalous involvement; but also to the character of the radiogram itself, which must be normal in that *it must be made in accordance with a technic which results in the shadows of the structures under scrutiny being imposed upon the plate or film in their correct proportions.*

Therefore, it is essential that in addition to the before mentioned requisites, *one who would intelligently interpret radiograms must understand enough of the fundamental rules of radiographic technic to know when examining a radiogram, whether or not the technic involved in its making was correct or faulty, and if faulty, whether or not the degree of fault is sufficient to render it so inaccurate as to be useless.*

In correctly made radiograms, the dental and oral structures under normal conditions have a characteristic appearance, for, owing to the varying densities of the contained structures in our field, they appear upon the plate or film in a manner most advantageous for observation. For instance, it will be noted upon the examination of such a radiogram, that metallic fillings, if they are present, appear as white masses, and root fillings as somewhat less dense lines. The enamel and dentin are next in density, while root canals show plainly as dark channels in the dentin, and the alveolar process and maxillæ show their fine uniform cancellous structures in vari-



A. B.

Fig. 61.—The radiographic appearance of the teeth and their surrounding structures under normal conditions are here shown. *A*, upper bicuspids and molars; *B*, lower molars.

ous degrees of density, depending upon their thickness. (See Fig. 61.)

In examining a radiogram, it is essential that the original plate or film only be used, and this should be examined carefully and in a proper light, if the maximum amount of information is to be obtained from it.

This is best accomplished by utilizing some sort of illuminating box or cabinet from which varied degrees of light are obtainable. The face of such a cabinet should be covered with ground glass, so that the light transmitted will be equally distributed and free from shadows. As a radiogram is a transparency, a dim light

behind it will bring out one set of shadows to their greatest clearness. An increase in the light will show forth still other effects; while a high degree of illumination will bring out the more dense portions.

In this manner each portion of the radiogram may be studied under a degree of light destined to bring out the maximum amount of detail.

Now with a "print" or "lantern slide" one can study the field only from a one light aspect and oftentimes in order to secure any detail in the higher or less dense areas, it will be found that the dense areas must be printed almost to an inky blackness. This fact accounts for the unsatisfactory appearance of many radiograms used as illustrations in our journals, for when reduced to halftone engravings, much of their valuable detail is lost.

In examining intra-oral radiograms, it is an advantage to place them in a film mount which will hold them securely and render it unnecessary to view them while being held between the fingers. Such a "mount" should preferably be made of celluloid with one side clear and the other side dull, which allows the light transmitted to be of the same character as that coming through ground glass.

If one be unfamiliar with the fundamental rules of radiographic technic, he can not know, when examining a radiogram, just what portions of it are to be relied upon to give dependable information, for as a rule, owing to anatomic arrangement of the structures in our field, only limited areas can be relied upon to be "in focus" in each radiogram. But if one is possessed of an accurate knowledge of the anatomy and physiology of the parts involved, understands the fundamental rules of radiographic technic, and is familiar with the appearance in the radiogram of the dental and oral structures under

normal conditions, *it should by no means be difficult to see any alterations or changes which occur in these structures as a result of anomalous or pathologic conditions.*

The mere ability to note an *alteration, or change,* in the structures does not fulfill the requirements of intelligent interpretation, for *these alterations, or changes,* can have their full significance only to one *who understands the pathologic conditions which may develop in these structures, and the character of the anatomic changes which they bring about.* Therefore, it should be apparent that the ability to intelligently interpret radiograms is not a thing to be acquired overnight, but must come as the result of study in several important branches, and anyone who attempts it otherwise assumes responsibilities unworthily.

Assuming that you are familiar with the appearance in the radiogram of the dental structure under normal conditions, let us consider some of the changes to be found in the presence of anomalous and pathologic conditions.

As a tooth is much more dense than the bony structures of the jaw or adjacent parts, any anomaly of form, size, or position, is easily discernible even though it occupy a position far from what might be expected; as, for instance, in the case of impacted molars, teeth in the antrum, etc. (See Fig. 62.)

Likewise, and for the same reason, the presence in, or absence from, the jaws of successors of the deciduous teeth can easily be determined, as well as the state of development of any unerupted tooth (Fig. 63).

Fractured roots or fractures of the bone even without displacement, are often discernible at the line of fracture, owing to the fact that the line of fracture offers less resistance to the penetration of the rays, and, therefore, is apparent upon the plate as a dark line.

Fig. 62.—A cuspid tooth lying against the anterior wall of the antrum. It will be noted that the cuspid is inverted in its position.

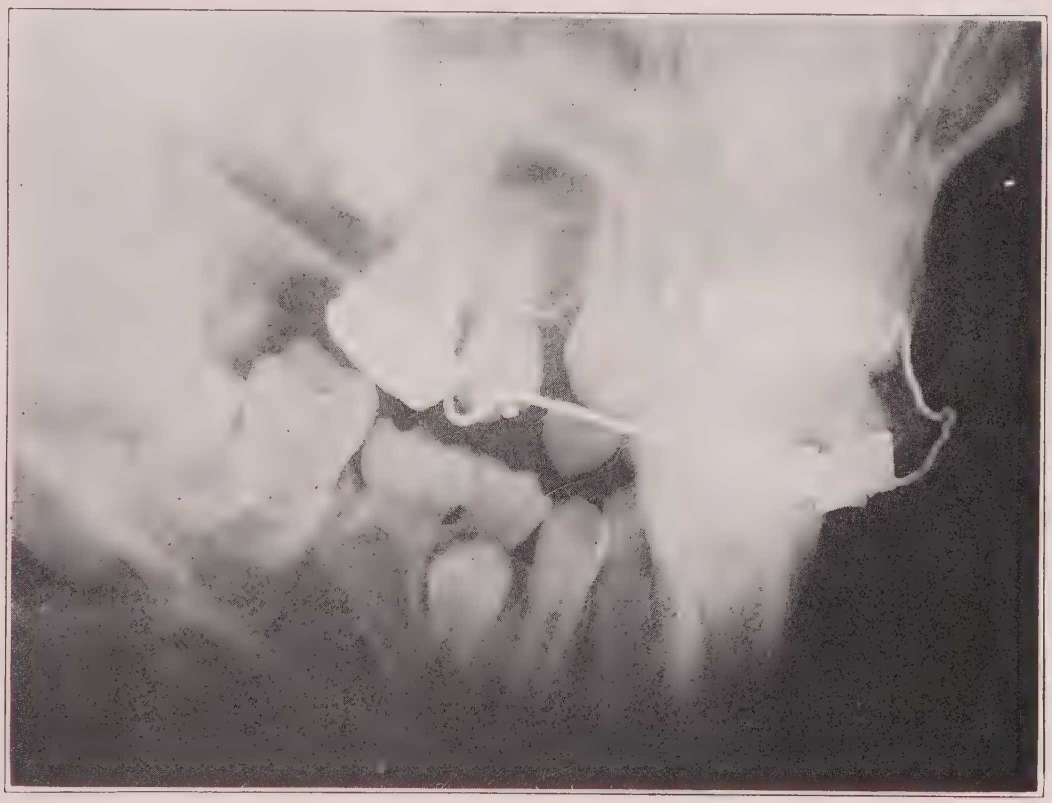


Fig. 63.—A radiogram to determine the state of dentition of the right side in the mouth of a child eleven years old. The developing second molars are shown, likewise the upper second bicuspid and the lower first bicuspid about to erupt. It will be noted that the lower second deciduous molar has no successor, nor is there an upper first bicuspid present in the jaw.

In examining radiograms, we should bear in mind the fact that very dense tissues are characterized by white areas, while less dense tissues appear darker, and the absence of tissue is indicated by blackness. To avoid confusion, we should remember that in ordinary negative photographic prints, this color spectacle is reversed.*

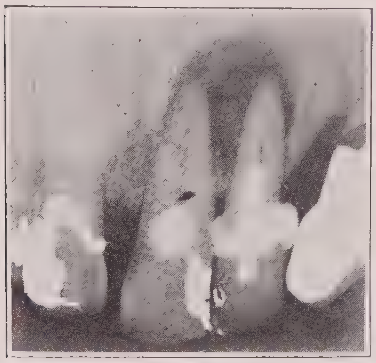


Fig. 64.

Fig. 65.

Fig. 64.—An alveolar abscess involving the roots of an upper central incisor and lateral incisor. No root canal fillings are present in either tooth.

Fig. 65.—There is evidence of a small alveolar abscess about the apex of the root of the first bicuspid, while a larger one is shown to exist about the apex of the second bicuspid.

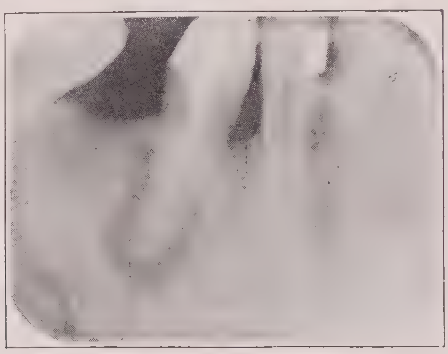


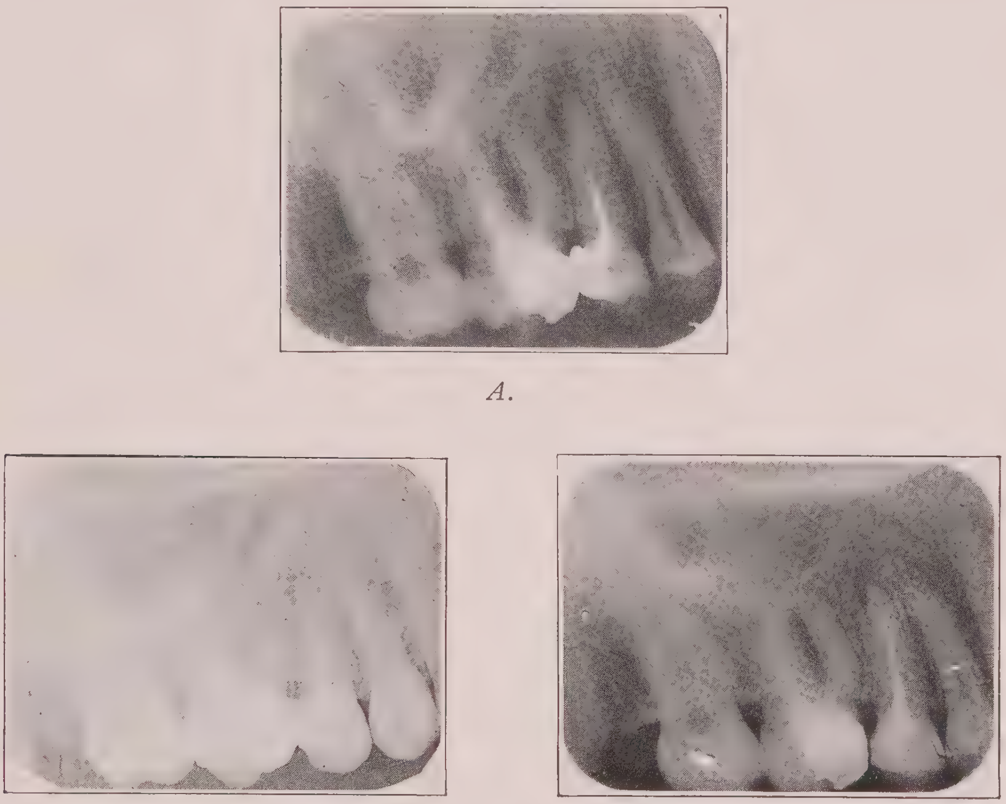
Fig. 66.

Fig. 66.—Large alveolar abscess about the root of a lower first bicuspid.

One of the most characteristic alterations or changes in the tissues to be noted in the radiogram, is that to be found where an alveolar abscess is present. We know that when such an abscess takes place there is always an accompanying destruction of the cancellous bone tissue

*In this text positive prints have been used so as to reproduce as nearly as possible the color spectacle of radiograms.

at the immedite seat of the inflammatory process. Knowing that the absence of tissue is indicated in the radiogram by a dark or black area, such an area if located at the apex of a devitalized tooth, or about a root or fragment of a root, would indicate the presence of an alveolar abscess. In fact, where these dark areas are found in the alveolar process, *and are not natural cavities,* such as the antrii, or nasal cavities, or such well-defined nerve



A. *B.* *C.*

Fig. 67.—*A* shows an upper bicuspid tooth with an alveolar abscess at its root apex. It will be noted that the root canal is improperly filled. *B* shows the same tooth about two months after it was treated and the root canal properly filled. The rarefied area about the apex has greatly decreased in size. *C* shows the same tooth about six weeks later. The abscess area has entirely disappeared and the bone structure about the apex appears to be normal.

openings as the mental foramina, and where they are *markedly* circumscribed, that is having a distinct and abrupt line of demarcation between the dark area and its surrounding tissue, we can in nearly every case, even if a clinical history be lacking, make the positive diagnosis of alveolar abscess. (See Figs. 64, 65 and 66.)

Not infrequently, dentists are prone to disregard such evidence, as these areas are often to be found about the apices of teeth giving no inflammatory symptoms. However, in the light of our present knowledge of these conditions, we know that this fact no longer carries weight, nor is it worthy of special consideration. The fact remains, as indicated in the radiogram, that a change has taken place in the structures, and such changes occur only as a result of the presence of an inflammatory process. Furthermore, it has been demonstrated that when such inflammatory processes are really

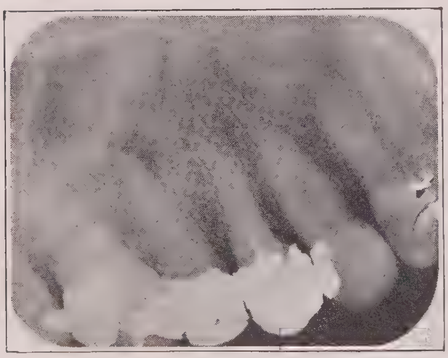


Fig. 68.

Fig. 69.

Fig. 68.—Small abscesses are shown at the apices of two upper bicuspid teeth. If in making the radiogram the images of the teeth had been lengthened as the result of incorrect technic, these areas would not be discernible.

Fig. 69.—A necrotic area about the roots of an upper central and lateral.

eliminated, the cancellous tissues involved will again regain their normal character. (See Fig. 67.)

Alveolar abscesses do not by any means present a "stereotyped" appearance in the radiogram, but vary greatly in size. For this reason, the smaller ones may sometimes be overlooked, or not be regarded seriously by those lacking the requisites of intelligent interpretation. Likewise, these small abscesses may sometimes not be apparent in the radiogram as a result of the employ-

ment of incorrect technic in the exposure of the plate or film. (Fig. 68.)

Necrosis likewise appears upon the plate as a dark area, but differs in a characteristic way from the ordinary alveolar abscess in that it is not circumscribed;

Fig. 70.—A necrotic area lying below a lower cuspid. It will be noted that there is not a distinct and abrupt line of demarcation between the light area and its surrounding tissue as is the case with alveolar abscesses, but the area gradually shades off from light into dark.

namely, *that there is not a distinct and abrupt line of demarcation between the dark area and its surrounding tissue,* as is the case with the circumscribed infections, but *the area gradually shades off from dark into light,* portraying the progessive characteristics of this disease. (See Figs. 69 and 70.)

The different filling materials vary but little in relative graduation of density, and when used as root filling materials, are plainly visible as light lines. Because they differ in density from cementum and dentin, the

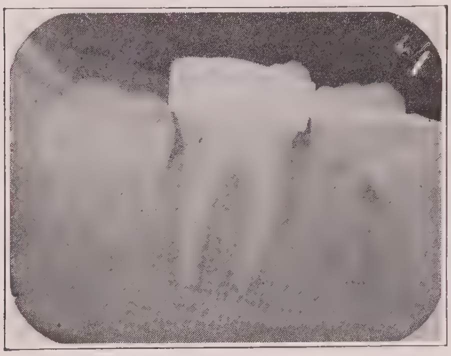


Fig. 71.

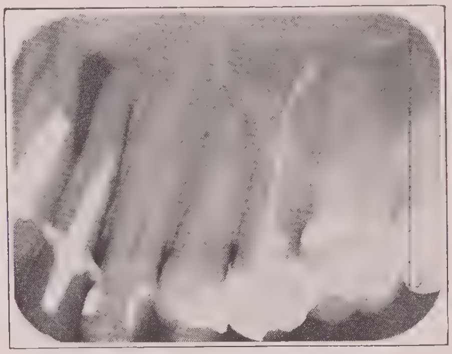


Fig. 72.

Fig. 71.—Root canal fillings in a lower first molar.

Fig. 72.—Root canal filling material forced beyond the root apex of an upper second bicuspid.

Fig. 73.

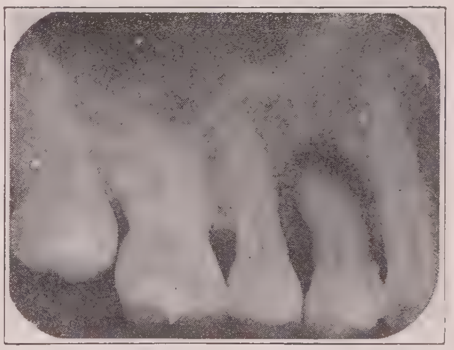


Fig. 74.

Fig. 73.—A steel wire introduced into the root canal to determine its length. It has passed through the apex and entered the antrum.

Fig. 74.—A destructive process involving the pericemental and alveolar tissues about an upper first bicuspid.

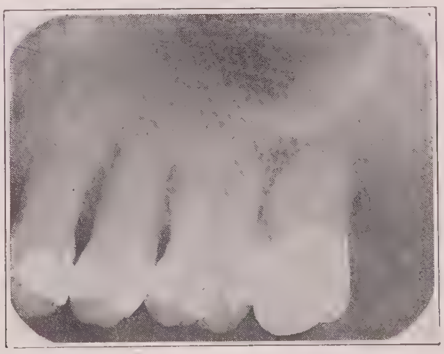


Fig. 75.—Characteristic appearance of the enveloping tissues about the upper bicuspids and molars in a well-developed case of pyorrhea alveolaris. Compare the condition shown here with that shown in Fig. 61-*A* and *B*.

extent to which they have been introduced into the root canals is easily discernible. (See Figs. 71 and 72.)

Broken-off broaches and other instruments, or small wires introduced into root canals to determine their length or the extent to which they have been opened, be-

Fig. 76.—An osteosarcoma of the mandible.

Fig. 77.

Fig. 78.

Fig. 77.—Well-developed cyst over an upper lateral incisor. Root filling material forced through the apex of the lateral incisor is plainly visible.

Fig. 78.—Well-developed cyst lying below the lower incisors.

cause of their great density, appear very white and are easily differentiated from root canal fillings or tooth structure. (See Fig. 73.)

Where a destructive process has ensued in the peridental membrane, or in the bony wall of the alveolus (pyorrhea pockets) and is present on the mesial or distal side of a tooth, these conditions appear upon the plate as dark areas owing to the fact that the rays pass through them more easily, and effect the emulsion of the plate to a greater degree than if normal bone structure is present. The approximate extent of the destructive process is, therefore, easily determined. (Figs. 74 and 75.)

Cyst and tumors of the maxilla or mandible, owing to the fact that the character of the changes they bring about renders the areas involved less dense, are visible upon the plate as a dark area. (Figs. 76, 77 and 78.)

In seeking out the various anomalies and pathologic conditions to which the teeth and oral structures are subject, *we should not be misled by indefinite shadows upon the x-ray plates.* The very nature of these structures, their gross, as well as minute, anatomy, renders them somewhat difficult to radiograph, and necessitates a refinement of technic greater than that demanded with most of the other portions of the human anatomy. *Therefore, only radiograms made in accordance with a definite and exacting technic should be relied upon for diagnosis. If a doubt exists in any given instance, an additional or even several more exposures should be made, so that any conclusions reached will be founded upon definite evidence.*

CHAPTER X

INDICATIONS FOR THE USE OF THE X-RAY IN THE PRACTICE OF DENTISTRY

Prior to the discovery of the x-ray and its adoption in dental practice, the diagnosis of many abnormal conditions in the alveolar process and in the maxilla or mandible proper had to be accomplished, or at least attempted by the dentist largely by relying upon his "judgment" and "experience." As these excellent attributes are not infallible, the progessive members of the profession were quick to recognize in the x-ray, a veritable godsend, because it rendered more positive and accurate than heretofore, the diagnosis of many pathologic conditions. It has also aided just as materially in prognosis and treatment. In fact, so indispensable has it become that if the dentist attempts certain operations without its aid, he assumes unworthily his professional responsibilities.

In enumerating the many instances where this agent should be used, the author will not attempt to give preference or importance to any particular field, or to classify the indications in the order of their frequency of occurrence, for this will depend largely upon the character of practice enlisting the efforts of different men. When the need arises for its use, *it should be used* whether the need arises in the practice of the orthodontist, prosthedontist, oral surgeon, or general practitioner, etc., for *the obligation* is the same if the dentist expects to do his full duty by his patients.

For Purposes of General Oral Examination

Not infrequently the dentist is consulted by patients who are undergoing no discomfort or pain from their

teeth, but realizing their importance as etiologic factors of systemic disease, wish to undergo a thorough examination. In many instances, such an examination will not be complete without a radiographic survey of the mouth. Especially is this true where such patients have pulpless teeth, or where large fillings, bridge work or crowns are present. Notwithstanding the fact that often the clinical history of such cases reveals nothing that will lead the dentist to believe that active septic foci have existed in such mouths, the radiographic examination should, nevertheless, be made, for in the light of our present knowledge, it must be concluded that these conditions frequently exist without subjective or objective symptoms.

Such examinations are particularly important in the case of patients suffering from some systemic conditions, who are referred by a physician to determine whether or not the teeth are an etiologic factor.

Where such an examination reveals no active septic foci, but shows the presence of one or several pulpless teeth with root canal fillings which do not measure up to the full requirements of such fillings, it is important that such teeth be resubjected to radiographic examination at regular intervals to see whether or not they remain in a healthy state.

Radiographic Requirements.—In order to do justice to such cases, extra-oral radiograms should be made of each side. These should show the upper and lower teeth and adjacent structures posterior to the cuspids. Intraoral radiograms of the upper and lower incisors and cuspids should also be secured, and the whole series developed and examined. (See Fig. 79.)

Where the extra-oral radiograms show suspicious areas about the teeth which do not show with sufficient clearness to meet the demands of diagnosis, intra-oral

radiograms may then be made of these areas, as a means of confirmation. (See Fig. 80.) Some operators prefer to use the intra-oral method entirely, in making a general examination, but this, in the author's opinion, is a mistake, for the reason that all areas of pathologic importance are not accessible to these small films.

Fig. 79.—Extra-oral radiogram of the right side made for purposes of general examination. Suspicious areas are to be seen above the upper first bicuspid and about roots of the lower second molar. An unerupted upper third molar is also visible.

To Determine the Seat of Pericemental Infections

Not infrequently it is a difficult matter to determine the tooth responsible for a pericemental infection or an alveolar abscess, as the inflammatory process may be in progress in the region of several teeth, each of which may be under suspicion, or the infected area may be at a point remote from the suspected tooth. A radiographic examination will quickly settle all doubts, for the radiogram will reveal the source and determine whether

or not one or more teeth are involved. It will likewise show the extent to which the periapical tissues have become involved and will often shed valuable information on the prognosis of the case. (See Figs. 81, 82 and 83.)

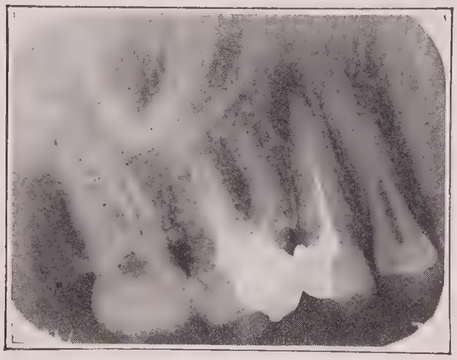


Fig. 80.

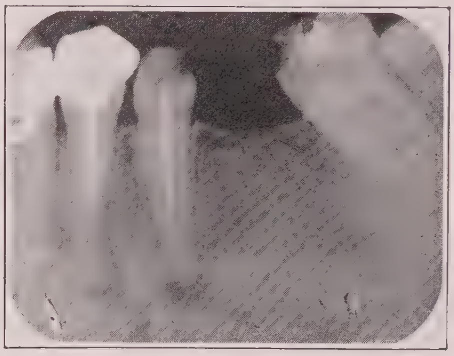


Fig. 81.

Fig. 80.—Intra-oral radiogram used as a means of confirmation of the findings of the extra-oral radiogram.

Fig. 81.—Alveolar abscesses are shown to be present at the apex of each bicuspid root.

Fig. 82.

Fig. 83.

Fig. 82.—Upper bicuspid teeth with abscesses.

Fig. 83.—Severe inflammatory process in progress about an upper lateral incisor. The root end shows a marked hypercementosis.

Radiographic Requirements.—Intra-oral radiograms will usually suffice. Where the lower molars and bicuspids are under examination, and the tissues under the tongue are very tender, the extra-oral method can be used to advantage, if the patient's comfort is a consideration. (See Fig. 84.)

Root Canal Treatment

Of the various dental operations, there is none that is more universally in need of further elucidation than the treatment and filling of root canals. As generally practiced at the present time, this work can easily be termed the "greatest shortcoming of dentistry." To those who recognize the uncertainty of results in this field, and the serious results which accompany failure to render sterile

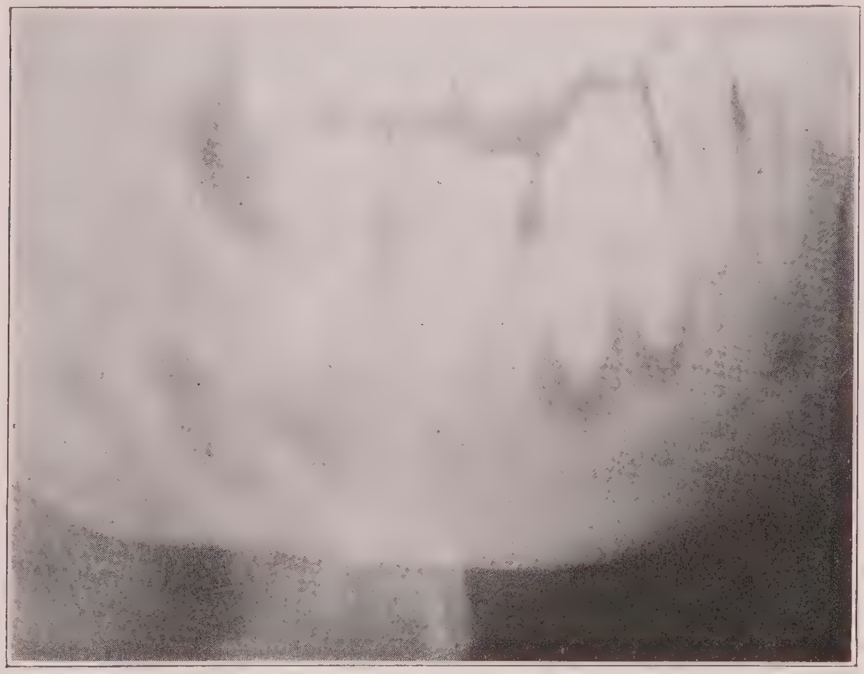


Fig. 84.—Extra-oral radiogram of the lower molars showing the presence of a large alveolar abscess.

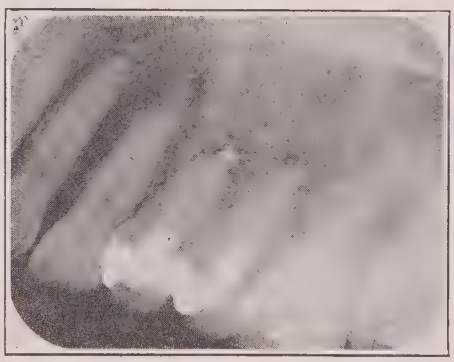
and to completely fill root canals, the x-ray offers indispensable aid.

Before considering the treatment of a tooth (or teeth), a radiogram should be made to show the topography of the roots to be treated. If these are proved to be anatomically within the range of treatment, an attempt may then be made to remove all organic material from the canals and to open them up to the very apical foramen. Fine diagnostic wires should then be inserted and carried to the end of the canal, or as far as the operator has

been able to introduce the broaches. After sealing them in with gutta percha, a second radiogram should be made. Because of their greater density, the wires will show distinctly in the radiogram and will enable the operator to determine to what extent the canal or canals have been opened. It will likewise determine whether any opening leading from the pulp chamber is a canal or a perforation.

A.

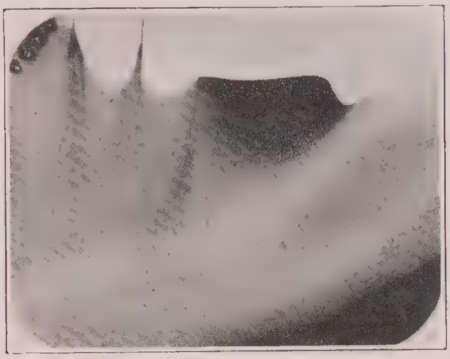
B.



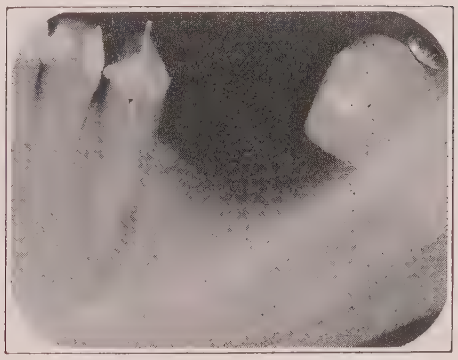
C.

Fig. 85.—*A*, two upper bicuspid teeth with imperfectly filled canals; *B*, the same teeth with the canals cleaned out and diagnostic wires in place; *C*, the same teeth after the root canals have been filled.

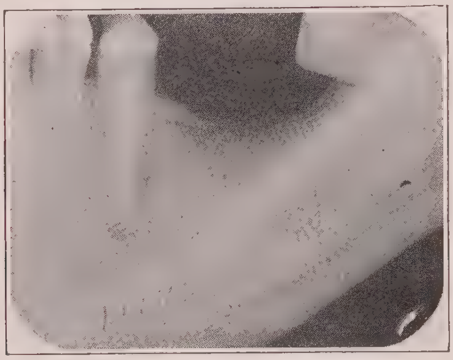
When the canals are open to the end (as shown by the inserted wires) and the necessary treatment and sterilization has been completed, the root canal fillings can then be inserted. Another radiogram should then be made to determine whether or not the root fillings extend to the apical foramina and seal the canals. If they do not, they should be removed and the before-men-



A.



B.

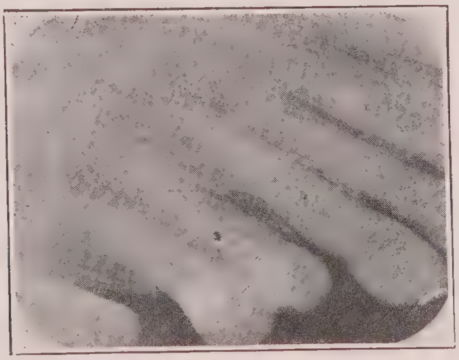


C.

Fig. 86.—*A*, lower second bicuspid needing root canal treatment and filling; *B*, same tooth with canal cleaned out and diagnostic wire in place; *C*, same tooth with the root canal filled.

A.

B.



C.

Fig. 87.—*A*, an upper first bicuspid needing root canal treatment and filling; *B*, canals have been cleaned out and diagnostic wires put in place; *C*, canals filled.

tioned operative and roentgenographic process repeated until success is obtained.

Even when all precautions are taken and results seem eminently satisfactory, several radiograms should be made at regular intervals of from three to six months following the filling of the roots, to determine whether or not the operation has been successful, so far as the periapical tissues are concerned. This is especially important where roots have been the seat of periapical infections prior to the time when treatment was inaugurated. (See Figs. 85, 86 and 87.)

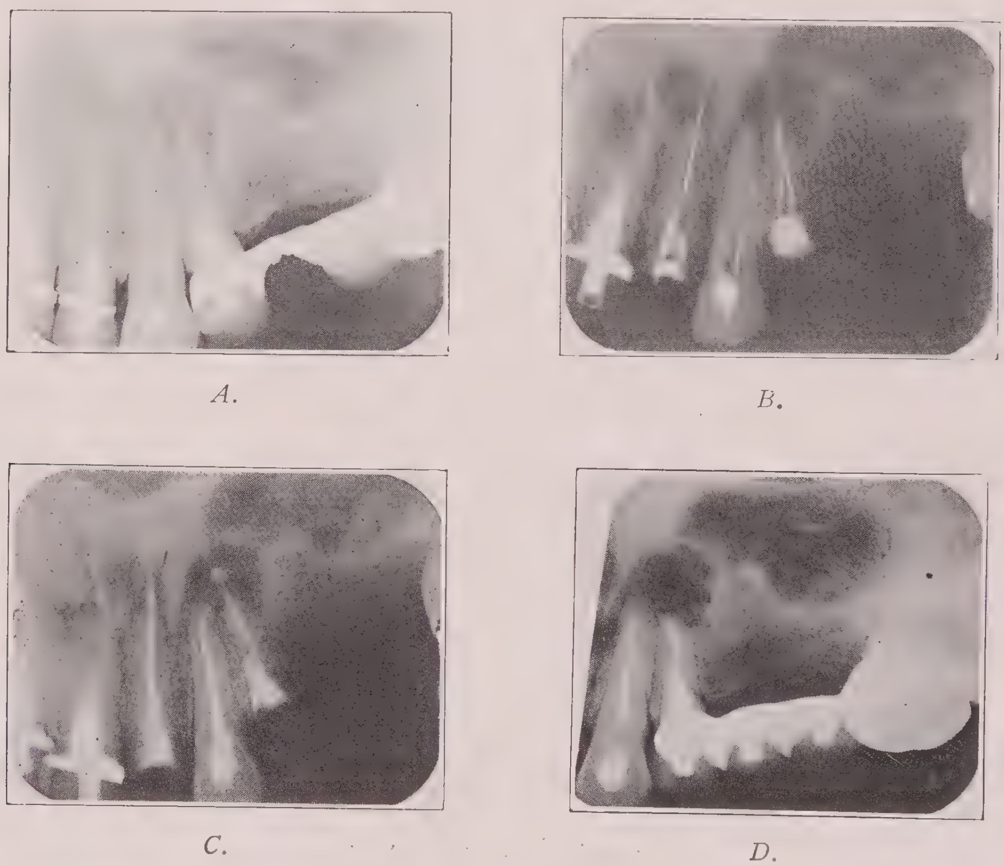


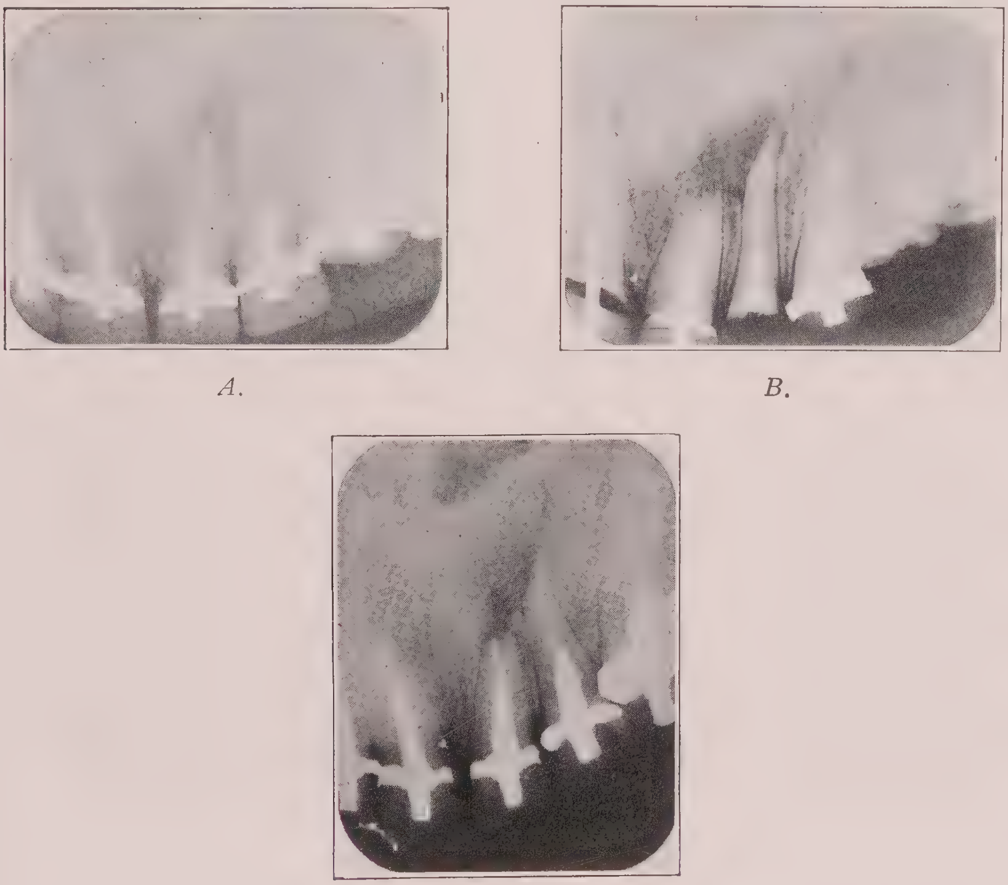
Fig. 88.—*A*, showing condition present; *B*, diagnostic wires inserted; *C*, root canals filled; *D*, resection of roots.

Radiographic Requirements.—Intra-oral radiograms exclusively should be used for this work. An exception might be made in the case of the lower molars and bicuspids, if the tissues under the tongue are sufficiently

tender to make the placing of the films for exposure a hardship to the patient. Excellent extra-oral radiograms of this area may be obtained, providing the operator has the ability and constancy to master the necessary technic.

Root Resection

Where root resection is contemplated, the intelligent dentist should first obtain accurate radiograms of the



A. *B.*

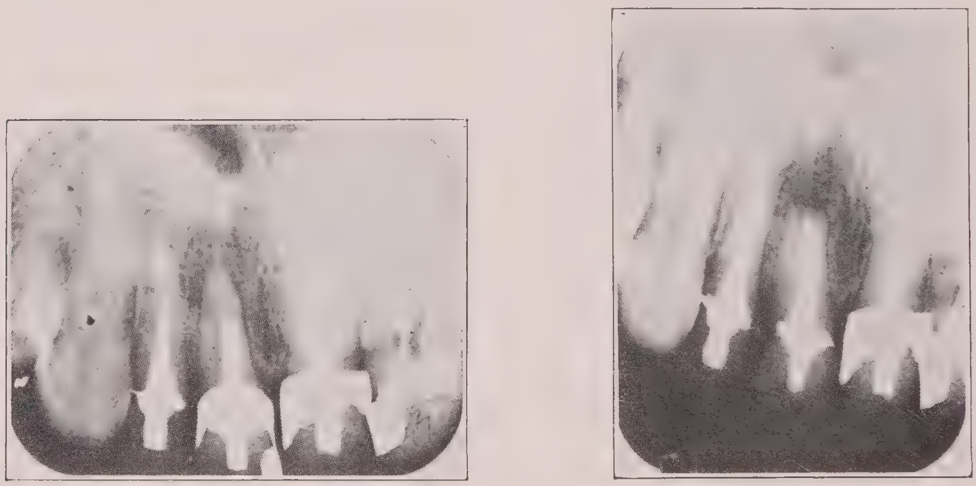
C.

Fig. 89.—*A,* upper central incisor before resection; *B,* radiogram made immediately following resection; *C,* radiogram made after several months, showing regeneration of osseous tissue.

roots under consideration. These aid him greatly, primarily in determining whether or not a resection is indicated, and if it is, it will give him a fairly concrete idea of the field of operation as well as the extent of the root to be resected; secondarily, in determining whether or

not the root canal has been sufficiently well filled so that the filling extends past the point where resection is to take place.

Following root resection, a radiogram should be made as a matter of record and be used for purposes of comparison as the process of healing progresses. Subsequently, additional radiograms should be made every three months to determine whether or not the process of bone-regeneration is progressing in a satisfactory manner. (See Figs. 88, 89 and 90.)



A. B.

Fig. 90.—*A,* an upper central root before resection; *B,* the same root six weeks after resection, showing partial regeneration.

Radiographic Requirements.—Intra-oral radiograms should be used exclusively. In fact, the necessity for anything else could hardly arise, as root resection is usually confined to the anterior teeth.

For Purposes of Examination and Diagnosis in Pyorrhea Alveolaris and Allied Diseases

A radiographic examination of the teeth and their investing structures is of great advantage in diagnosis and treatment. In the first place, accurately made radiograms will often show the extent to which the destruc-

tive process has progressed, especially if areas of absorption and "pockets" exist upon the mesial or distal aspects of teeth. Even where such areas are visible to the eye, the radiogram serves an important function in acquainting the patient with the true state of affairs, thereby securing the patient's cooperation in the treatment. (See Fig. 91.)

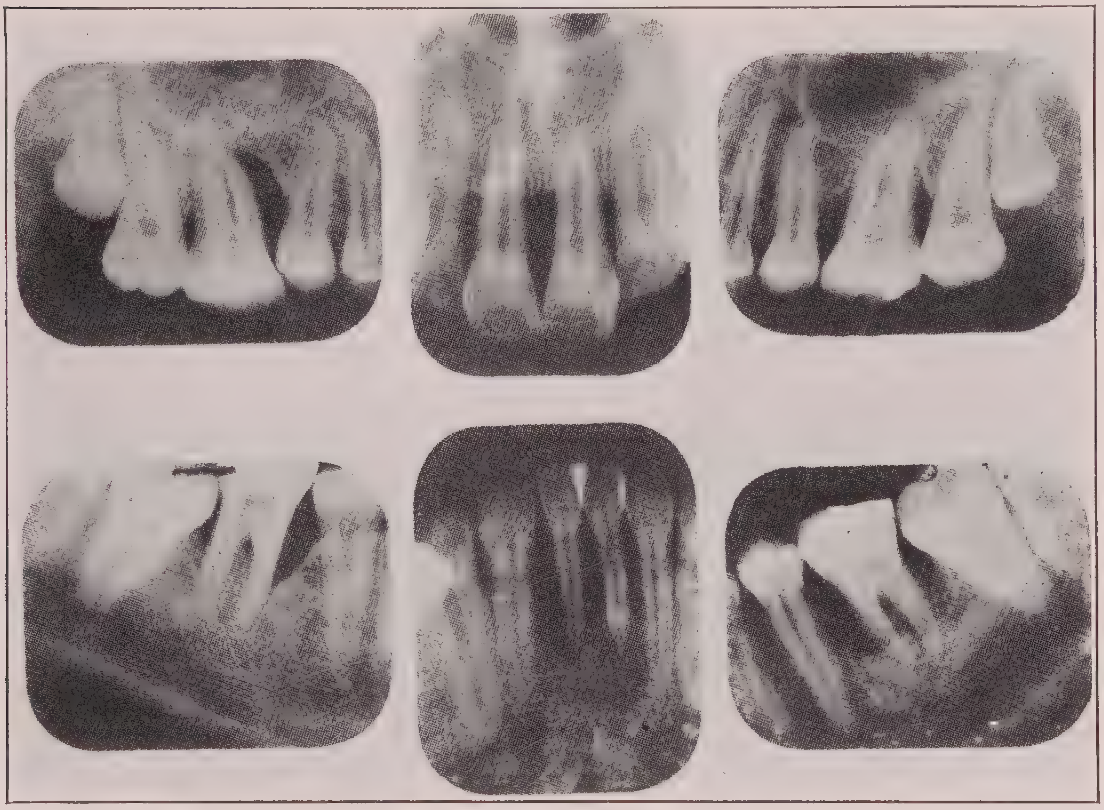


Fig. 91.—A well-developed case of pyorrhea alveolaris involving the molars and incisors. (After Arthur H. Merritt.)

When the destructive process is shown to be extensive about certain teeth, the operator can more safely judge whether or not the treatment of such teeth should be attempted or whether they should be extracted.

Where suppuration is occurring at the gingival margin. the radiogram is often indispensable in helping to determine (by showing the contents of the root canals) whether the adjacent teeth are vital, and if nonvital

whether or not the suppuration is due to a chronic alveolar abscess.

In cases of gingival irritation about crowned teeth or teeth carrying large fillings or inlays, a radiogram will reveal jagged or overhanging edges, the removal of which is so essential if the tissues are to be restored to health.

Finally, the radiogram or a series of radiograms will be of value after active treatment has been completed, to determine whether or not the destructive process has been successfully checked.

Radiographic Requirements.—Intra-oral radiograms will suffice for such cases, as pockets seldom extend below the apical area of the roots. Such radiograms should be made in series, so that no area about the teeth is left unsurveyed.

In Crown and Bridgework

Where teeth are to be crowned individually, or as bridge abutments, the radiogram will give valuable information, not only as to the length and shape of the roots, and the condition of the investing structures, but also as to that of the periapical tissues. Where the necessity for the devitalization of such teeth occurs, the operator can also judge by the shape and condition of the roots whether or not the prognosis for successful root treatment and filling is favorable.

Where "posts" are to be placed in the roots, their extent and direction can be noted, and where the anatomic peculiarities of such roots make them liable to perforation, precautions for avoiding such calamities may be taken.

Where spaces are to be bridged, and the exact status of the area which is to lie beneath the bridge is not known, a radiogram should be made to be sure that unerupted teeth or root fragments are not present. (See Figs. 92, 93 and 94.)

Radiographic Requirements.—Intra-oral radiograms are indicated for this character of work.

Reflexes of Obscure Origin

Where painful reflexes occur about the face or head, and a clinical examination does not immediately determine their possible origin, a radiographic examination of the teeth and their adjacent structures is indicated. Where such reflexes are the result of unerupted, im-

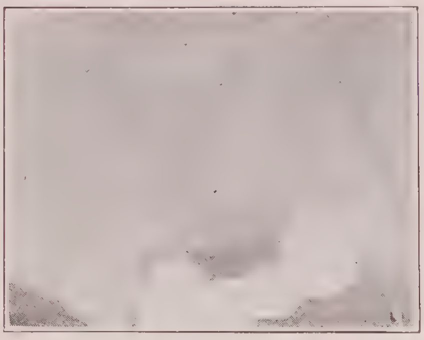


Fig. 92.

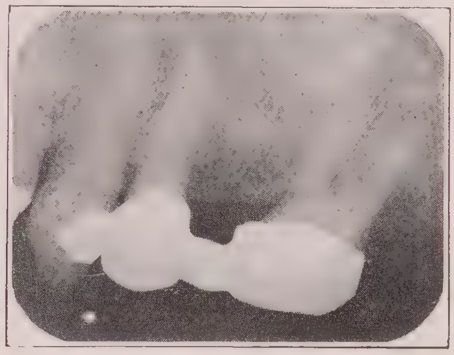


Fig. 93.

Fig. 92.—An unerupted cuspid tooth making an attempt to erupt under a bridge. The patient was twenty-eight years of age.

Fig. 93.—Radiogram made to be sure no root fragments were present in the tissues under the bridge.

Fig. 94.—Inflammatory process under a small bridge. An extensive pocket is shown upon the mesial aspect of the root of the bridge abutment.

pacted, or anomalous teeth, the presence of any of these is quickly demonstrated. Likewise, if the reflexes are caused by an alveolar abscess, its presence can be thereby determined.

Where pulp stones are producing the trouble, they can often be detected, if intense care is exercised in making

the radiograms. If these reflexes are the result of "hidden caries," the radiogram will frequently suggest the presence of such a condition, providing the cavities occur upon the mesio-or disto-approximal surfaces of the teeth, and are sufficiently extensive so that the density of the tooth structure in the region of the cavity is decreased, or the contour of the tooth is altered.

Radiographic Requirements.—Approximately the same plan of examination should be used as where a general radiographic examination of the mouth is made; viz., extra-oral radiograms of each side with intra-oral radiograms of the anterior teeth. These can be further augmented with confirmatory intra-oral radiograms, if necessary. (See Figs. 79 and 80.)

In Oral Surgery

Perhaps the most frequent indication for the use of the x-ray in oral surgery occurs in cases in which the extraction of certain teeth is necessary. For instance, if one or more third molars are to be removed, a radiogram of these teeth and their surrounding structures will acquaint the operator with any abnormalities of position or formation, and will make it possible to proceed with the operation without unknown handicaps.

Following the removal of teeth, a radiogram of the field of operation is often of value as a matter of record, to make sure that no root fragments or bone fragments are left remaining.

Where necrotic areas are to be curetted, a radiogram not only aids greatly in confirming the diagnosis, but gives the operator a more comprehensive idea of the extent to which the curettement must be carried out. As a postoperative precaution, the radiogram is also frequently of value, especially where the process of healing does not progress in a manner satisfactory to the pa-

Fig. 95-*A*.

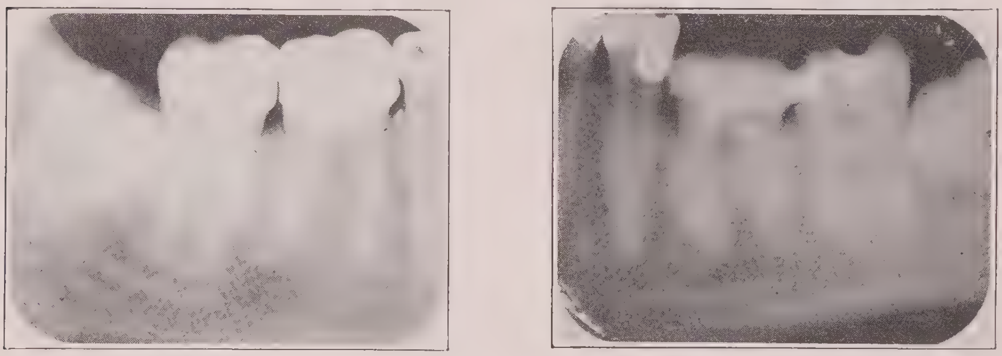
Fig. 95-*B*.

Fig. 95.—Extra-oral radiograms of impacted and unerupted third molars.

tient or operator. Such postoperative radiograms are particularly advantageous where patients move from one locality to another, and, therefore, must change surgeons.

In handling fractures of the mandible, the x-ray is seldom necessary for purposes of diagnosis, but it can often be used to advantage, and in some instances, is quite indispensable. As a postoperative precaution it should be used so that no doubt may arise as to the proper placement of the fractured parts.

Where fractures of the maxilla occur, a radiogram may be of value as a means of confirming the clinical diagnosis.



A. B.

Fig. 96.—Intra-oral radiograms of impacted lower third molars. Such radiograms are not as satisfactory as those made by the method shown in Fig. 95.

Where cysts or tumors are suspected, the radiogram will confirm the clinical findings, and comprehensively outline the field of operation. Following operations for the relief of those conditions, radiograms should be made at frequent intervals to determine whether or not the process of healing is progressing satisfactorily.

In gunshot wounds about the face or mouth, properly made radiograms will localize the bullets or shot, and thereby aid in their removal, as well as in determining the extent of injury to the osseous structures.

Where drills, hypodermic needles or other instruments are broken off and left remaining in the tissues, they may

Fig. 97-*A*.—Large cyst in the mandible lying below a molar tooth.

Fig. 97-*B*.—Same case six months after curettement, showing partial regeneration of the osseous structure.

be easily located by correctly made radiograms, and their removal rendered more certain.

Radiographic Requirements.—Both the extra-oral and intra-oral radiograms are indicated in this field. For impacted third molars, the extra-oral method is best, as it will clearly show not only the third molar, but its relationship to all other adjacent structures. In the case of single-rooted teeth, such as incisors, cuspids, etc., where hypercementosis is suspected, the intra-oral method will prove adequate. (See Figs. 95, 96 and 97.)

Fig. 98.—Large abscess with cyst formation involving the upper central, lateral and cuspid roots.

Where a curettement is to be carried out, intra-oral radiograms will prove sufficient, provided the field is not large (Fig. 98.)

In fractures of the mandible, the extra-oral method should always be used, so that the entire field in the region of the fracture can be visualized.

For fractures of the maxilla, intra-oral radiograms will usually suffice.

In the Practice of Orthodontia

The necessity for using the x-ray in orthodontic practice varies with different patients, but, generally speak-

Fig. 99.—This radiogram reveals the fact that there is a congenital absence of permanent molars on the left side.

Fig. 100.—This radiogram reveals the fact that all but one of the permanent molars are congenitally absent on the right side.

ing, may be summarized under ten different headings as follows:

1. As a means of determining the presence or absence of unerupted permanent teeth before treatment is undertaken.

The majority of patients requiring orthodontic treatment usually have a mixed dentition; viz., the deciduous molars and cuspids are usually present. It is essential, therefore, to determine whether or not these deciduous teeth have their permanent successors. If the upper and lower incisors have erupted, information concerning the other permanent teeth is easily obtained by making a radiogram of each side by the extra-oral method. Such radiograms are shown in Figs. 99 and 100.

Such radiograms give the operator a very adequate survey of these unerupted teeth, and leave no doubt as to their presence or absence.

2. As a means of determining the approximate size of unerupted teeth, for which space must be made in the arches.

Where the deciduous molars or cuspids have been shed prematurely, with the usual resultant loss of space in the arch, the radiogram can be made to show quite accurately the amount of space which it will be necessary to prepare for the unerupted teeth. (See Figs. 101, 102, and 103.)

3. To determine the state of development of unerupted teeth which are tardy in their eruption.

Not infrequently permanent teeth fail to erupt when expected. By utilizing the radiogram, their state of development is easily determined, and often the cause for their noneruption is determined. Steps can then be taken to open up spaces and to hold them until such a time as the teeth involved progress in their development to the point of eruption. (See Fig. 104.)

Fig. 101.—Unerupted lower second bicuspid for which space must be made to permit its eruption.

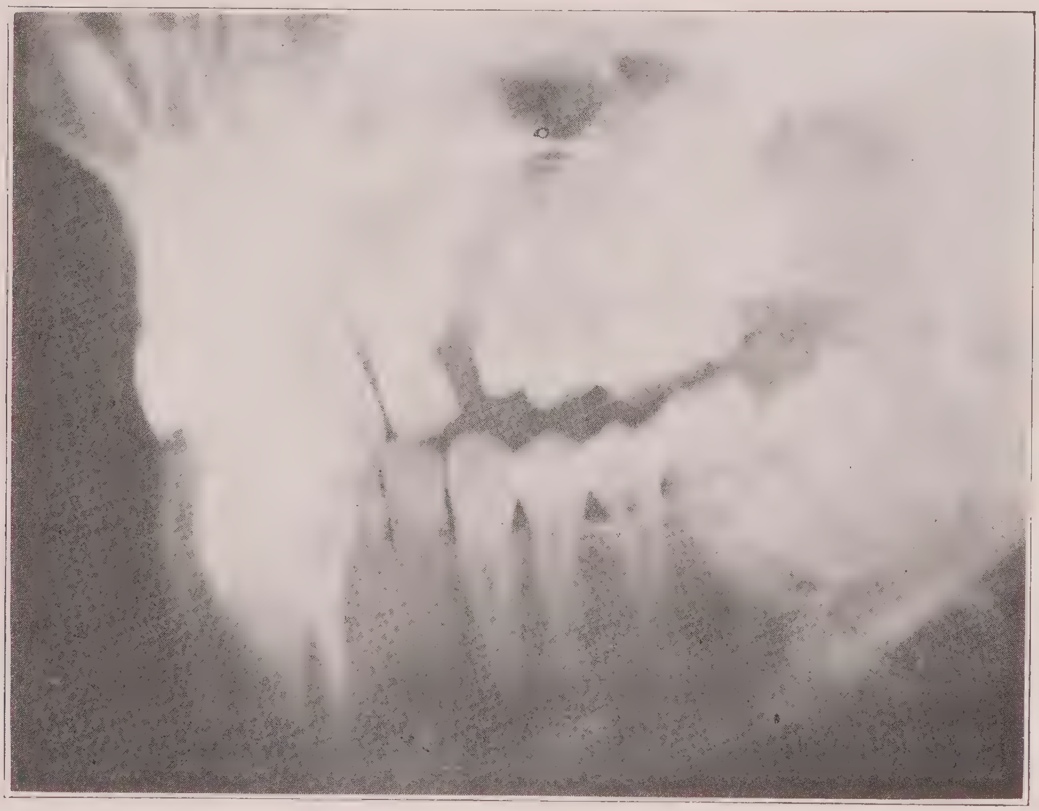


Fig. 102.—Unerupted cuspid for which space must be made if it is to erupt in its normal position.

Fig. 103.—Unerupted lower lateral incisor for which space must be made.

Fig. 104.—Unerupted lower second molar prevented from erupting through impaction against the lower first molar.

4. To determine the approximate direction in which teeth are erupting and the relationship which they will bear to the line of occlusion when erupted.

Where the deciduous teeth have been retained in the mouth longer than the normal time and where the roots of these teeth have not been entirely absorbed, the erupting permanent teeth will sometimes be deflected from

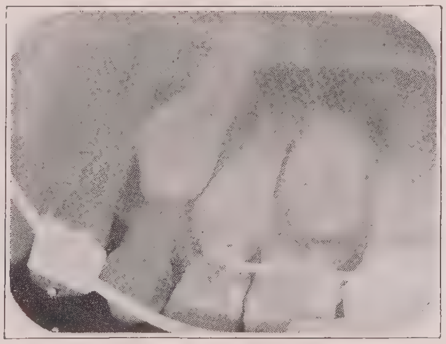
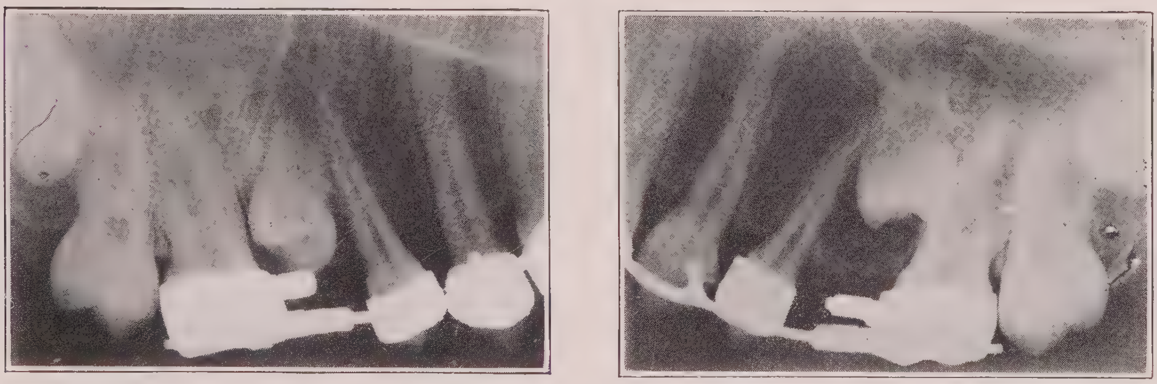


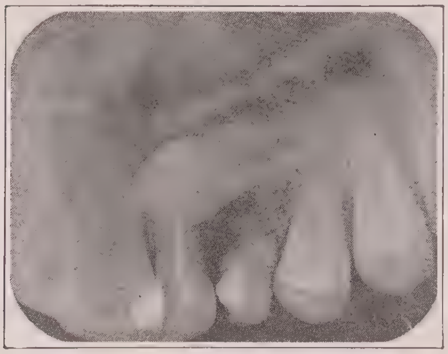
Fig. 105.—Unerupted upper bicuspid teeth which are being deflected to the lingual.



A. *B.*

Fig. 106.—Unerupted bicuspid teeth which are rotated and erupting to the lingual.

their normal course. It is an advantage to know the direction in which they are deflected, so that if retaining appliances are to be placed, they may be arranged in such a way and in such a relationship to the erupting teeth that they will not interfere with them. In fact, it is sometimes possible to construct the retainer in such a way that the tooth which is deflected from its course may be guided towards its normal position or moved

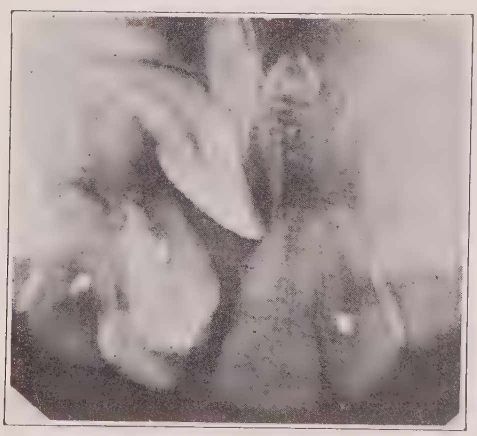


A.

B.

C.

Fig. 107.—*A*, unerupted cuspid; *B*, same tooth after the removal of the lateral incisor and the deciduous cuspid showing the attachment for moving the unerupted tooth; *C*, cuspid tooth moved down to the point of eruption.



A.

B.

Fig. 108.—*A*, two supernumerary incisors are present with the normal central lying above them; *B*, the same case after the extraction of the supernumerary teeth. An attachment has been made to the central preparatory to moving it down into place. The patient was fourteen years of age.

there before the inclined planes of the opposing teeth become a factor in establishing it entirely out of its normal position. (See Figs. 105 and 106.)

5. As a guide where it is necessary to make attachments to unerupted teeth, to aid in their eruption.

While it is not often necessary to secure attachments to teeth lying beneath the gingival tissues, the occasion for this sometimes arises, as shown in Figs. 107 and 108. In such cases, radiograms should be made as a guide in securing the attachment. After the attachment is secured, others should be made to determine the direction in which force should be applied to accomplish the desired tooth movement.

6. To determine the most opportune time for the extraction of the deciduous teeth.

Where the deciduous tooth persists in the mouth, and shows no sign of being shed, it is an advantage to determine the extent of absorption of the roots, as well as the development of its successor, so that if extraction is resorted to, it can be done with the knowledge that the developing tooth will not be disturbed or injured, and that the successor has reached a degree of development which will insure its eruption within a reasonable time. (See Figs. 109 and 110.)

7. To observe the movement of the roots of teeth and their relationship to other roots and structures.

In the bodily movement of teeth, and particularly of the incisors, it is important in young subjects that these roots do not encroach upon each other or upon other teeth; for instance, an unerupted cuspid. It is therefore, advisable, where any doubt exists, to determine the exact status of this relationship. (See Fig. 111, A, B, C.)

8. To determine the relationship of developing third molars to certain recurrent malocclusions, and also as a precaution so that steps may be taken to prevent these

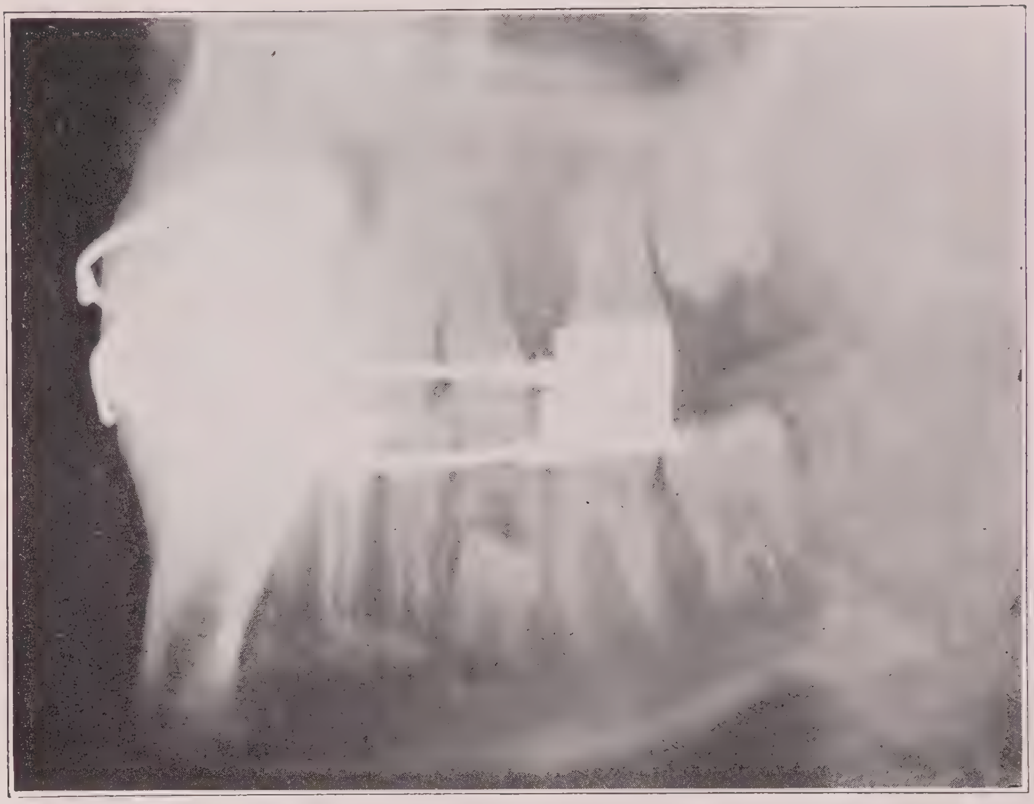


Fig. 109.—An unerupted lower second bicuspid in a patient twelve years old.

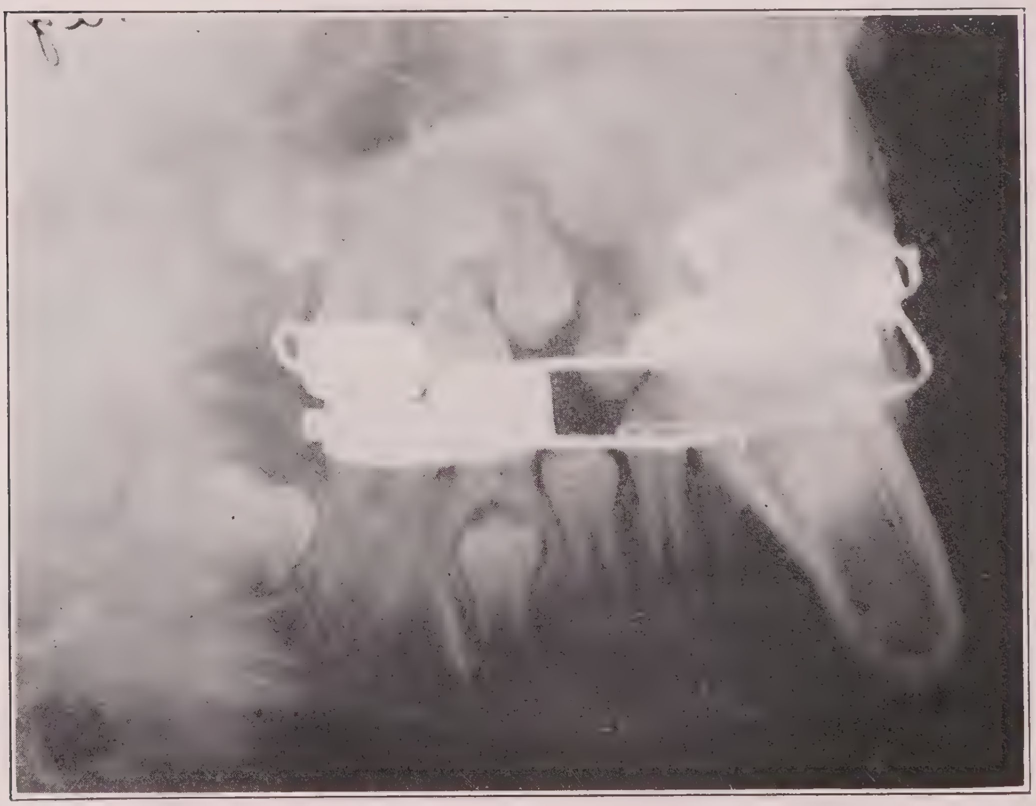
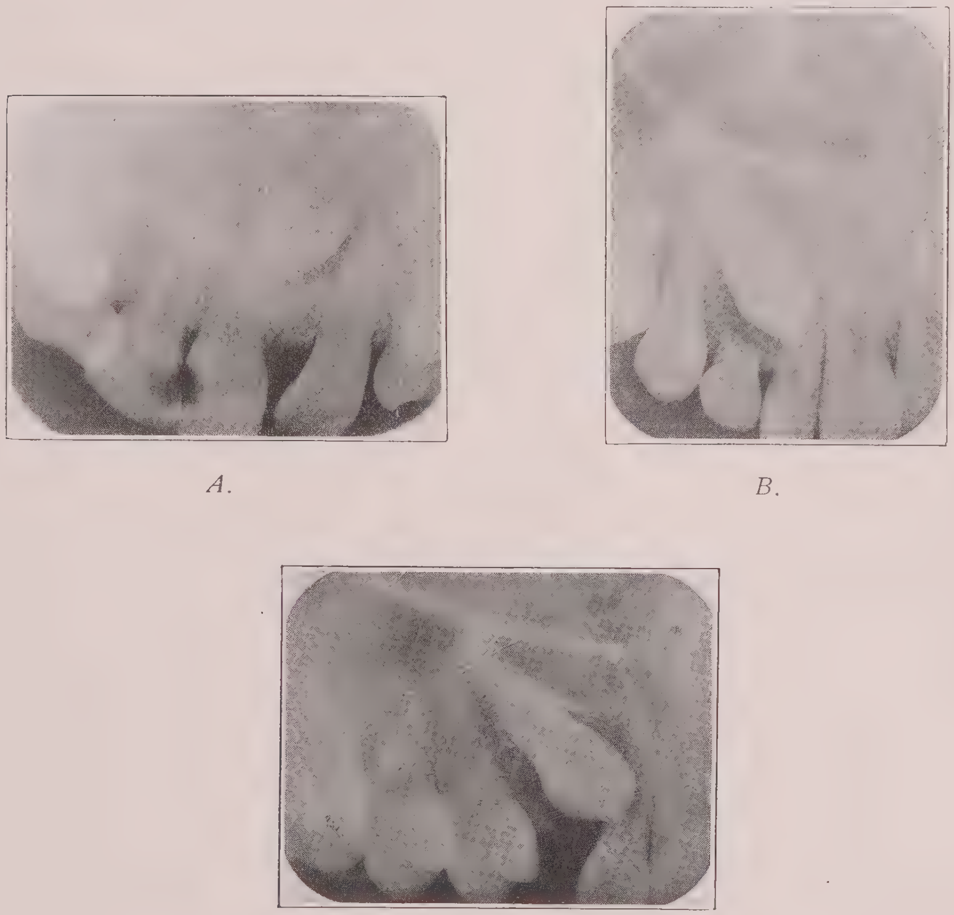


Fig. 110.—Unerupted upper and lower bicuspids in a patient eleven years of age.

teeth from becoming a cause of malocclusion during their eruption.

The pressure exerted by developing lower third molars is often sufficiently great to cause a crowding of the lower incisors and cuspids. (See Figs. 112 and 113.) This can be true, even though malocclusion has not existed in this region previous to the development of the third molars. By making radiograms from time to time of patients at the age of the eruption of these teeth, the status of the developing teeth can be determined and the necessary precautions taken to prevent the crowding of the incisors and cuspids.



A. *B.* *C.*

Fig. 111.—Unerupted cuspid teeth whose relationship to the roots of the incisors must be taken into consideration during tooth movement.

9. To observe nonvital teeth prior to tooth movement,

Fig. 112.—An unerupted lower third molar which is crowding the incisors.

Fig. 113.—An erupting lower third molar which has been responsible for the crowding of the lower incisors and cuspids.

to determine their fitness for movement or anchorage, and their state of health during the process of orthodontic treatment.

Where it is necessary to either move nonvital teeth, or utilize them as anchorage, it is essential to the patient's welfare and comfort to know that such teeth and their investing tissues are in a healthy condition. By determining this prior to instituting orthodontic treatment, much trouble, both to the patient and operator, can often be avoided. (See Fig. 114.)

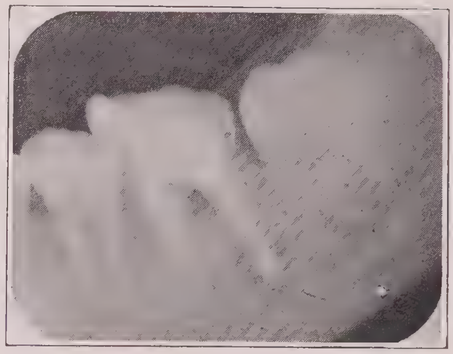
10. In cases where anomalous teeth are present, to differentiate between anomalous and normal teeth.

In a majority of instances, this can be done without the aid of the radiogram, unless the teeth in question have failed to erupt. Under such conditions, by utilizing accuracy in the technic of making the radiograms, little difficulty is encountered in determining the difference between normal and anomalous teeth. Examples are shown in Figs. 115, 116, and 117.

Radiographic Requirements.—Owing to the fact that patients undergoing orthodontic treatment are usually children whose ages necessitate their being handled with tact and gentleness, if confidence is to be maintained, precaution should be taken to rid every operation of fear or discomfort. Especially is this essential in making radiograms, for any considerable degree of movement on the part of a patient will either curtail the value of the finished radiogram, or render it useless.

In selecting a method of procedure for making radiograms of children, the child's comfort must be taken into consideration, and with this idea in mind, the author has found it an advantage to use the extra-oral method quite universally. In fact, he has used it in nearly all cases except where the region embracing the upper anterior teeth is under scrutiny. The wisdom of

A.



B.

Fig. 114.—*A*, nonvital tooth being used as an anchor tooth; *B*, nonvital tooth which was not considered safe for anchorage.

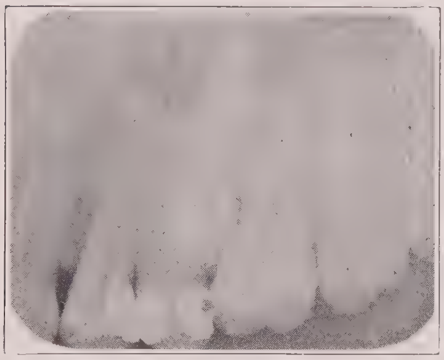


Fig. 115.

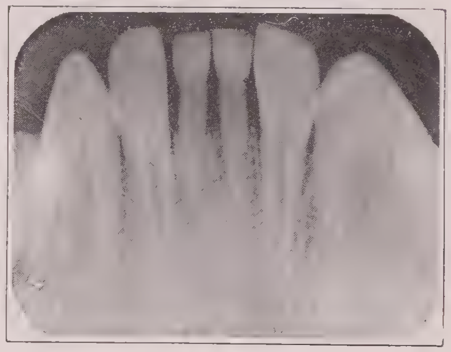


Fig. 116.

Fig. 115.—Supernumerary upper second bicuspid. Upon the extraction of the supernumerary, the normal tooth erupted.

Fig. 116.—Lower deciduous central incisors having the appearance of supernumerary teeth. The radiogram leaves no doubt as to their identity, and also shows that these teeth have no permanent successors.

Fig. 117.

Fig. 117.—Radiogram showing either an anomalous central incisor or a central incisor lying in a horizontal position to the other teeth. The patient was sixteen years of age.

Fig. 118.—The patient is seated and the apparatus arranged to make a radiogram of the left side. Fig. 99 shows the extent of radiograms made by using this technic.

Fig. 119.—The patient is seated and the apparatus is arranged to make a radiogram of the right side. Fig. 100 shows the extent of radiograms made by using this technic.

this course will be apparent to anyone who has experienced the discomfort of having intra-oral films placed lingually to the lower teeth, where the tissues are very sensitive, or has had them placed posteriorly in the molar region, against the palate, where they so frequently induce gagging. These unpleasant features are all eliminated by using the extra-oral method, and good radiograms of the structures can be secured on the larger plates. (See Figs. 118 and 119.) This statement should not be construed as a protest against the use of intra-oral films in dental radiography, for it is very often necessary to use such films with adult patients where a high degree of detail is essential, in determining the condition about nonvital teeth, root canal fillings, etc. In orthodontic practice, however, where we are dealing with young subjects entirely, a sufficient degree of detail can be obtained in the majority of instances to satisfy the needs of the operator, by using the extra-oral method.

CHAPTER XI

DANGERS OF THE X-RAY AND METHODS OF PROTECTION

Almost invariably when any phase of x-ray work is discussed, some one raises the query as to the dangers connected with it and the injuries resulting from its use. In fact, the impression is quite broadcast among the laity, and to a degree among the profession, that the x-ray is a dangerous agent and as such should only be employed in cases of dire emergency.

This impression, erroneous as we know it to be for the most part, gained credence as a result of the first few years' use of the x-ray, during which period its dangers were not suspected nor the laws governing its use well understood. During this period a sufficient number of patients and operators were injured so that, notwithstanding the fact that with our present knowledge of the subject and with the marked improvement in x-ray apparatus these accidents are no longer necessary, the early impression still prevails to a certain extent.

In order that we may not underestimate the dangers of this valuable agent and consider lightly our responsibility in using it, we will now consider the character of injuries possible through its misuse.

We should bear in mind the fact that the x-ray in medicine serves a double purpose. It is used as a diagnostic agent; that is, in making radiograms and fluoroscopic examinations, and as a therapeutic agent. In the latter capacity patients are subjected to repeated exposures, the length of which are very far in excess of

that required in making radiograms. In fact the length of exposure in one average x-ray therapy treatment will more than out-total the necessary exposures to radiograph a half dozen patients for diagnostic purposes. Therefore, the responsibility of the x-ray therapist, and the danger connected with his work are far in excess of the man who limits his activities with x-ray to radiography alone.

Of the various ill effects attributed to the x-ray, the so-called "x-ray burn" or dermatitis is the most common. This injury occurs in various degrees of severity, depending upon the amount of overexposure to which the one afflicted has been subjected, and is designated as "acute" and "chronic."

Acute X-ray Dermatitis

Acute x-ray dermatitis in its simplest form manifests itself in somewhat the same way as ordinary sunburn. There is a slight pinkish erythema, dry in character, accompanied oftentimes by the sensation of tingling or burning. If x-ray exposures are continued, this condition is augmented by the appearance of vesicles and the affected surface becomes moist or "weeping," and the patient has similar sensations as those produced by any blistering burn. If exposures to the ray be discontinued at this stage, the affected area will slowly clear up with no permanent ill effect except perhaps a slight pigmentation.

If the exposures be continued, the next degree of dermatitis will ensue. The affected area becomes an angry red in appearance, congestion is intense, and the surface is covered with a yellowish white necrotic membrane, which is epithelial in character. In fact, up to this point the connective tissue is not affected except for more or less swelling. This degree of dermatitis is exceedingly

slow in healing, months being required for the necrotic membrane to disappear, and when this has occurred it is followed by a horny epidermis which appears in spots over the area affected, eventually covering it. This new skin while smooth and natural looking is usually characterized by the absence of all hairs and follicles.

The most severe form of acute x-ray dermatitis is characterized by somewhat the same symptoms as those just described, except that they are greatly exaggerated. The degree of congestion is very great, the necrotic membrane extends deeper into the tissue, necessitating the surgical removal of masses of dead tissue to prevent gangrene. This sloughing or necrotic area shows a strong tendency to spread and according to some authors, is apt to become malignant. With such a dermatitis patients often suffer very intense pain. Injuries of this degree of intensity are exceedingly slow in healing, a number of years sometimes being necessary for the process of reconstruction. Even after it occurs, the skin is not natural in appearance, but hard and horny and covered in places with scar tissue.

Chronic X-ray Dermatitis

After a person has been exposed to the x-ray a great many times covering a period of perhaps months or years, and has had one or more "burns" which were not allowed to heal before new effects were added by additional exposures, the dermatitis which results becomes "chronic." This chronic x-ray dermatitis is confined almost entirely to x-ray operators and others constantly associated with the x-ray. The hands because of their exposed position are most often the seat of this affection. The skin becomes thin and atrophic with red patches of a vascular nature, and there is usually an entire absence of all follicles and hair. Codman describes

this condition as follows: "In the less pronounced forms the skin appears chapped and roughened, and the normal markings are destroyed; at the knuckles the folds of skin are swollen and stiff, while between there is a peculiar dotting resembling small capillary hemorrhages. The nutrition of the nails is affected so that the longitudinal striations become marked and the substance becomes brittle. If the process is more severe, there is a formation of blebs, exfoliation of epidermis, and loss of nails. In the worst form the skin is entirely destroyed in places, the nails do not reappear and the tendons and joints are damaged."

Another author states that "while the condition in chronic forms of x-ray irritation is as a whole atrophic, there is usually a peculiar tendency to hyperkeratosis, which shows itself in increased horniness of the epidermis about the knuckles and in the formation of keratotic patches. In some cases this is very marked, so that the affected parts, usually the backs of the hands, have scattered over them many keratoses with or without inflamed bases. The appearance is very similar to that seen in senile keratosis where the patches are inflamed and have a tendency to epitheliomatous degeneration. The development of epitheliomas in these patches of x-ray keratosis has within the last few years been well established." Carcinoma may also have its origin from the same source, in fact many x-ray operators who have failed to take the proper precautions have been subject to this dreaded malady, the hands being the parts most often affected.

Other Ill Effects

In addition to the before described injuries, there are still other ill effects attributed to the x-ray, such as loss of hair, sterility, and certain systemic effects. The loss of hair due to x-ray exposure is not to be regarded seri-

ously, unless it is associated with a dermatitis of sufficient severity to destroy the hair follicles, for unless this complication is present, the hair comes back within five or six weeks.

The x-ray has a deleterious effect upon developing embryonic cells and can therefore be the cause of sterility in the male by destroying the spermatozoa, and in the female by the destruction of the primordial ovules. This condition is brought about by continued exposures, and x-ray operators are the ones usually affected. It is not accompanied by impotence, is temporary in duration, and can be avoided entirely by adopting protective measures.

Regarding the so-called injurious systemic effects produced by the x-ray, too little evidence of a convincing character has yet been presented to really fasten the blame upon the x-ray for conditions other than those before enumerated. Therefore, until its guilt is scientifically substantiated, we must not indict it for conditions which may be but coincident with its use.

Methods of Protection

The evil effects of the x-ray can be entirely avoided by utilizing the protective measures afforded in modern x-ray apparatus. Inasmuch as lead is impervious to the rays, it can be used in different forms and in various pieces of apparatus in such a way as to control or confine the rays according to the will of the operator.

Tube Shield

The most essential piece of protective apparatus is the tube shield (Fig. 120). This is constructed of leaded glass, there being a sufficient amount of lead salts incorporated in the glass to prevent ordinary rays from passing through it. The sides extend up over the highest

part of the tube and the opening at the top is often covered with a rubber cap, in which lead is also incorporated. At the bottom directly opposite the target of the tube an opening of the proper size is left to allow the desired rays to pass out. The size of this opening may be controlled by interchangeable diaphragms of various sizes, which are constructed of sheet lead about one-sixteenth of an inch in thickness.

This apparatus is usually augmented by a compres-

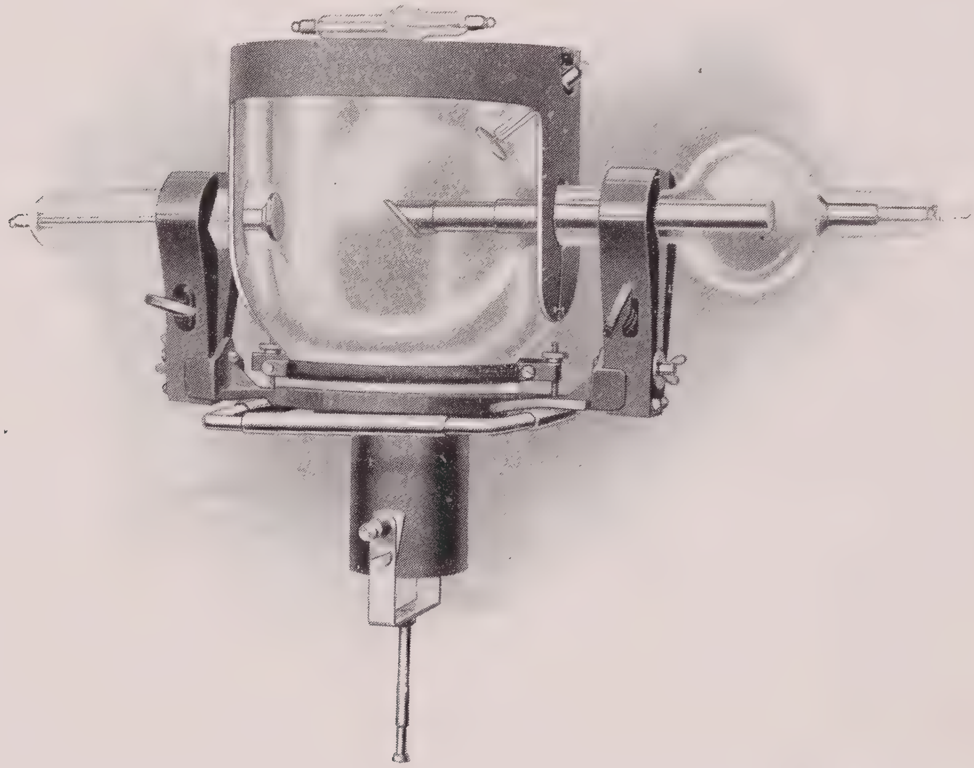


Fig. 120.—An x-ray tube inclosed within a leaded glass tube shield.

sion cylinder, which is attached to the base of the tube shield, against or in contact with the lead diaphragm. Such a cylinder is usually constructed of aluminum with a lead lining, is made in various lengths and diameters according to the character of the work for which it is to be used, and serves the purpose of confining the rays coming through the diaphragm from the target of the tube.

These pieces of apparatus are usually integral parts

of the modern tube stand, sold by all reliable manufacturers of x-ray apparatus. It should be apparent to anyone that with such apparatus, the only rays which leave the area of the tube are those which pass through the diaphragm and cylinder and are used upon the pa-

B.

Fig. 121.—Types of lead-lined protection screens.

tient. In radiographic work these do not injure the patient, as the exposures are too short to produce ill effects, even if numerous exposures are necessary.

On the other hand the radiographer who fails to use these protective measures, or who carelessly places him-

self in the direct path of the rays will in time through the accumulative effect of the x-ray be very apt to reap as a result of his folly some of the dread injuries before described.

Other Means of Protection

In addition to the protective measures thus far described, there are other means that afford additional protection, and if a person is working constantly with the x-ray these should be used. Among these is the leaded screen behind which the operator stands during the time exposures are made (Fig. 121). Such a screen is usually placed in front of the controlling apparatus and has a leaded glass window, so that the operator can watch the

Fig. 122.—Lead-impregnated glove.

patient during the exposure. Lead-impregnated gloves (Fig. 122) and aprons (Fig. 123) are also used by some as a precaution, but such extreme measures are not necessary for the dentist doing his own radiography.

With a properly constructed leaded glass tube shield, lead diaphragm, and lead-lined cylinder the operator is safe, provided he takes the precaution of avoiding the direct rays.

We all realize that many very useful agents in medicine and surgery are dangerous when used carelessly, indiscriminately, or may we say ignorantly. The old saying that "fools rush in where angels fear to tread," perhaps applies with greater significance in many branches of medicine than we would care to admit. But the fact

that through the misuse of dangerous agents, many patients have met death, or have been subjected to needless suffering, is no argument against their use when placed in competent hands. In such hands the x-ray

Fig. 123.—X-ray protection apron.

stands today as one of the greatest adjuncts to the modern art of healing, a blessing to humanity, even if in its early history it left its martyrs here and there; its benefits and triumphs far out-balance any evils connected with its use.

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